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CHARACTERIZATION AND CONTROL OF ASBESTOS EMISSIONS FROM OPEN SOURCES

IIT RESEARCH INSTITUTE

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The report reviews control technology applicable to asbestos emissions from open sources including asbestos mines, mills, and manufacturing waste piles. It combined a literature review with visits to asbestos mining and manufacturing operations, and considered climatology, location, and topography. The study, which included preliminary field sampling, produced a comprehensive bibliography on emissions control. The health effects of asbestos exposure were reviewed from two aspects: the significance of fiber size, and the effect of non-occupational exposure. Fiber size considered to be most harmful is still not established and, while non-occupational exposure probably does not lead to asbestosis, evidence relates it to increased incidence of cancer. The U.S. asbestos industry has been reluctant to adopt control technology for its mining and waste dumping operations which is already available for other industries; probable reasons include the relatively small, low profit nature of the industry and the relatively recent recognition of the hazardous nature of asbestos. All eight U.S. mine sites were contacted; three others are no longer operational. Data analyses indicated that asbestos can be detected at considerable distances from a given source. It was concluded that, because of their proximity to populations, asbestos manufacturing waste piles are a threat to public health more serious than asbestos mining.

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ABSTRACT

The report reviews control technology applicable to asbestos emissions from open sources including asbestos mines, mills, and manufacturing waste piles. It combined a literature review with visits to asbestos mining and manufacturing operations, and considered climatology, location, and topography. The study, which included preliminary field sampling, produced a comprehensive bibliography on emissions control. The health effects of asbestos exposure were reviewed from two aspects: the significance of fiber size, and the effect of non-occupational exposure. Fiber size considered to be most harmful is still not established and, while non-occupational exposure probably does not lead to asbestosis, evidence relates it to increased incidence of cancer. The U.S. asbestos industry has been reluctant to adopt control technology for its mining and waste dumping operations which is already available for other industries; probable reasons include the relatively small, low profit nature of the industry and the relatively recent recognition of the hazardous nature of asbestos. All eight U.S. mine sites were contacted; three of them are no longer operational. Data analyses indicated that asbestos can be detected at considerable distances from a given source. It was concluded that, because of their proximity to populations, asbestos manufacturing waste piles are a more serious threat to public health than asbestos mining.

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SECTION 1

CONCLUSIONS

The control technology applicable to open sources of asbestos emissions have been reviewed. Particular attention was given to mining operations and to waste dumps. Site visits were made to asbestos mines and preliminary emission data was collected at one mine and two waste dumps.

Only five of the eight asbestos mine sites in the United States were active, and all but two have stated their intention to close during 1974. All of the mines, active or inactive, are located in remote rural areas. The control of emissions from mining operations is virtually non-existent. Techniques used in other industries in controlling emissions from drills, blasting, and haulage and dumping operations utilizing, for example, sprays, foams, and enclosure are rarely applied in the asbestos industry.

Waste dumps from asbestos product manufacturing operations are frequently located in high density population areas. Emissions are created both at the time of transfer of waste to the dump and when the surface is eroded by weather action. Present emission control methods, where applied, are inadequate. Dumps in other industries are stabilized using physical, chemical, or vegetative coverings and transfer operations are controlled by sprays, foams, and enclosures.

Preliminary ambient air samples were collected using membrane filters at two waste dumps and one mine site. Further, ambient air data from a waste dump was supplied by the Environmental Protection Agency. The samples were analyzed by optical and electron microscopes. The distance travelled by the asbestos fibers was predicted using the Climatological Dispersion Model.

It was found that fibers smaller than 1.5 μm exceeded those greater than 1.5 μm by about three orders or magnitude. Typically, about 10^4 fibers per cubic meter greater than 1.5 μm, and 10^7 fibers per cubic meter smaller than 1.5 μm were found at a source. The rate of reduction in the number of fibers per cubic meter as a function of distance was slow. At a distance of ten kilometers from the source, the number of fibers per cubic meter greater than 1.5 μm was typically about 10, and the number of fibers smaller than 1.5 μm was about 10^4. Beyond ten kilometers, the information from the model was eratic and unreliable.

Despite extensive research over the past decade, medical authorities still disagree on the health significance of asbestos exposure. While it is known that asbestos can produce asbestosis and cancer, the exact dose relationship, the most harmful fiber size, and the mechanism of disease induction, are still not precisely defined. It is extremely unlikely that the answers to these important questions will be known for some years to come.

It is concluded that in the light of the reported number of cases of cancers resulting from non-occupational exposure to asbestos, that it is necessary to implement methods of reducing emissions from open sources, particularly those sources in urban regions.

SECTION 2

RECOMMENDATIONS

Phase I of this program was limited to a review of the control technology applicable to the emission of asbestos from open sources. In order to assess the significance of open sources in terms of population exposure levels, a preliminary field sampling study was included.

It is recommended that waste dumps, because they are located in heavily populated areas and have been shown to emit large numbers of fibers, should be studied further. Asbestos mining operations, although they emit more fibers than do waste dumps, are regarded a less serious health threat because they are few in number and because they are found in very remote unpopulated areas.

Transfer operations at waste piles where asbestos is dumped, crushed, and spread can be seen to raise visible clouds of dust. There is a need to study methods of abating this dust. It is recommended that the use of spray systems, foams, or total enclosure should be tested.

Waste dumps are subject to erosion by wind, rain, sun, and frost action. Methods are available to stabilize the tailings piles from various mining operations using chemical, physical, and vegetative coverings. Their applicability to asbestos waste piles should be tested and their effectiveness established.

Technical feasibility and economic evaluation of all potential methods for reducing emissions from asbestos waste dumps and transfer operations should be undertaken. Field testing of those options deemed to be most applicable is recommended. Cost effectiveness data on these options can then be performed.

It is desirable that further improvements to the Climatological Dispersion Model should be made. The objective would be to extend the distance from the source to the receptor for which the results are valid.

The fate of sub-micron aerosol particles suspended in ambient air has not been sufficiently studied. Limited studies have shown that the scavenging action of rain and snow is extremely inefficient. The possibility is very real that they remain suspended for very long time periods and that they are continually increasing in concentration. It is recommended that the life cycle of asbestos emissions should be studied.

SECTION 3

INTRODUCTION

Open sources of asbestos emissions include mines, dumps, and storage areas. In the United States, asbestos mines are located in four states; Arizona, North Carolina, Vermont, and California. They are located in areas of very low population densities. Dumps and open storage areas associated with asbestos product manufacturing are frequently found in areas of high population density.

The original objective of Phase I of this program was to review the control technology applicable to the emission of asbestos from open sources. In particular, mining operations, dumps, and storage areas were to be considered. This was to be accomplished by a review of the literature and by visiting the asbestos mine sites. As a part of the survey, attention was to be given to the location of the mines and their climatology and topography.

Under a modification to the program, the scope was extended to include a preliminary field sampling study. The revised plan was not an in-depth study; only a minimum amount of data was to be obtained. Emission data obtained at one mine and two dumps was to be subjected to analysis using the Environmental Protection Agency's Climatological Dispersion Model. Used in conjunction with local annual weather rose and demographic data, an assessment of the health significance was to be made. The sites selected for emission sampling were the Coalinga Asbestos Company (a division of Johns-Manville) mine at Coalinga, California, and the waste dumps at the Johns-Manville asbestos cement products manufacturing plants at Waukegan, Illinois and Denison, Texas.

Under a further modification to the program, the results of a study conducted at the waste dump of the Certain-Teed and Nicolet Industries asbestos cement processing plant at Ambler, Pennsylvania was incorporated into the study. The samples had been collected by the Environmental Protection Agency, Environmental Standards Enforcement Division, and analyzed for asbestos content by the Battelle Memorial Institute.

As a result of Phase I of this study, the open sources of asbestos emissions which are considered to be most significant will be established.

SECTION 4

LITERATURE REVIEW

INTRODUCTION

The literature on asbestos is extensive. However, papers pertinent to the present study are quite limited. In this section, the literature relating to health effects and to the control of emissions from open sources is reviewed.

Two aspects of the health effects problem are of particular significance to the present study. They are the effect of fiber size on the hazard potential, and the effect of non-occupational exposure to asbestos.

Literature on the control of emissions from open asbestos sources is extremely limited. For this reason, the control of emissions from mining and dumping operations in other industries was reviewed. The open sources reviewed included overburden removal, drilling, blasting, loading, hauling, dumping, storing, field fabrication, and waste disposal. In addition, the natural asbestos outcrops, constituting very large areas from which emissions may be released, were reviewed.

ENVIRONMENTAL EXPOSURE TO ASBESTOS

The Affect of Fiber Size

The size range of asbestos fibers that are potentially dangerous to health is not yet established. Occupational safety standards consider the number of fibers in a given air sample which have a length in excess of 5 μm and an aspect ratio of greater than 3:1, length to breadth. The standard is based on the resolution limits of the light microscope rather than any known effects of fiber size on health. It is effectively an index of exposure rather than a measure of absolute emission.

The validity of an exposure index can be seriously criticized, particularly when applied to non-occupational situations. It is generally recognized that aerosolized particles greater than 5 μm in size are small in number compared to those less than 5 μm. The difference can, in fact, be several orders of magnitude[1]. In the case of asbestos, the ratio will be affected by the efficiency of the gas cleaning system (where used), and the length of time the fibers are airborne. This latter factor will determine the removal of fibers from the atmosphere by gravitational deposition, and the scavenging action of rain and snow.

As yet, there are no accepted health standards based on the number of fibers less than 5 μm in length. The potential adverse health effect of these fibers is being debated. Selikoff[2] believes they are harmful based on his findings that they are present in the lungs of a very high percentage of the population of the United States, including those who have died from lung cancer and mesothelioma. Other scientists[3] state that small fibers are cleared from the lung by phagocytosis action and that only large fibers remain lodged in the lung. They attribute the presence of small fibers to the break-up of large ones after they become lodged in the lung. Other scientists argue that since only small fibers are capable of penetrating into the narrow passages of the lung, they are the dangerous fibers.

A significant contribution to this controversy, based on experimental data, is that of Stanton, et al[4]. It is his finding that fibers in the size range of 10 to 100 μm in length promote tumors, while below this size the harmful effects are very much reduced. His work has been criticized because of the method of exposure whereby a fiber glass patch containing a 40 mg portion of asbestos was attached to the pleura by surgery. Thus, the asbestos bypassed the normal defense mechanism of the respiratory system.

Other workers, however, have found that small fibers may be harmful. Wagner and Berry[5] have produced a superfine sample of asbestos from standard Grade 7 asbestos samples. The finest material was selected by water sedimentation. Meseotheliomas were readily produced in hamsters and rats following intra-pleural inoculation of this asbestos. The same result was found by Timbrell and Rendall[6] using asbestos samples ground to a fine size.

Other workers have been unable to induce any fibrogenic activity with short (< 5 μm) fibers. Gross[7] has injected rats intratracheally with large doses of fibers less than 5 μm in length and no tumors were produced. Similar lack of success in inducing tumors were reported by Smith[8] and by Hilscher[9], and as referenced by Gross[7]; separate studies of Claysen, Davis, and Swinbourne. The latter three researchers did not publish their works because of their negative findings.

A possible reason for this lack of success[10] is the conversion of the asbestos to a non-crystalline material by the heat generated during the grinding of the asbestos to a small size. This is contradicted by the fact that wet grinding was used by Smith[8], that a microtome method was used by Hilscher[9].

It should also be realized that in the animal experiments, massive dosages were used to accelerate the incubation period. That is, the period from the initial exposure to asbestos to the onset of malignancy. For man, this incubation period is thought to be 20-30 years. There is, as with all such animal studies, some question as to the validity of the acceleration techniques.

Asbestos in Non-Occupational Areas

A number of studies have shown asbestos is present in the general atmosphere. A study of air pollution from an asbestos mine in Finland, by Laamanen, Noro, and Raunio[11], found asbestos at distances up to 50 km from the mines. Dust fall rates were measured at 1.52 g/100 m^2/month at 4 km and 34.6 g/100 m^2/month at 0.5 km. At the asbestos quarry, dust levels of 7.5 to 100 mg/m^3 were found; it was estimated that between 1 and 5.4% was asbestos.

Schepers[12] describes the dust from asbestos mines and mills in South Africa, which rolled through like a morning mist. They claimed that food in a local hotel was gritty with dust. In 1947, Sluis and Cremer[13] reported dust counts measured by optical microscope to be 80 to 840 fibers/cc in mines and 162 to 1,920 fibers/cc in mills of South Africa.

Bobyleva, et al[14], measured asbestos originating from asbestos manufacturing plants at distances of 40 to 80 km (25 to 50 miles). In surveys taken at three different plants in the U.S.S.R., they found concentrations ranged from 0 to 6,000 $\mu g/m^3$ at distances of 3 km, at 1.0 to 1.5 km it was 3,000 to 33,000 $\mu g/m^3$, and 0.5 km it was 6,000 to 34,000 $\mu g/m^3$.

Lumley, et al[15], monitored the emissions from an area in which crocidolite and amosite asbestos were stored. Light microscope analysis of the collected samples showed that levels of up to 52.6×10^6 fibers/m^3 were found in areas where the air was disturbed by worker activity.

A survey of optical count levels for asbestos in buildings which contained some asbestos-based materials in their construction was made by Byrom, et al[16]. The results were found to vary with the type of building and the construction material used. In the lowest instances, 5,000 fibers/m^3 were recorded, while in the highest, levels of 80,000 fibers/m^3 were found. Buildings not containing asbestos construction materials were found to contain 4,000 fibers/m^3. This latter figure presumably represented the background level of asbestos.

Nicholson[17], and Selikoff[18] have reported ambient air asbestos concentration figures for a number of large cities. New York City asbestos levels were found to vary between 11 and 60 ng/m^3, while near a fire-proofing operation, levels of 15 to 180 ng/m^3 were recorded. Philadelphia gave 45 to 100 ng/m^3, Ridgewood, New York, gave 20 ng/m^3, and Port Allegheny, Pennsylvania, gave 10 to 30 ng/m^3.

Simecek[19], in Czechoslovakia, investigated the dust in an asbestos ore processing plant and its surroundings. It was found that dust in the neighborhood of the mine was fairly constant throughout the year at a level of 0.033 to 0.392 mg/m^3. About 1% of this dust was estimated to be asbestos, giving 330 to 3,920 ng/m^3 asbestos.

A striking number of mesothelioma cases were reported by Bohlig[20] among the people residing near large asbestos factories and shipyards in Hamburg, Germany. No exposure levels are reported, and none were estimated because emission controls have improved during the past 20 years.

Mesotheliomas have occurred after short exposures to asbestos and in those exposed at home to dusty clothing or to a neighboring source of asbestos air pollution. A survey of these findings in the London area of England was made by Newhouse and Thomson[21]. Similar results following light exposure have been reported by Lieben[22] and by Wagner[23].

Exposure to asbestos through water supplies has come very much to the public attention largely through the litigation proceedings resulting from the contamination of Duluth's water supplies by the Reserve Mining Company. Taconite tailings dumped in Lake Superior have been found to contain a large number of fibrous particles of the amosite type. Sargent[24] studied a number of water supplies in the Vermont area. The conclusion is that asbestos cement pipe will add to the asbestos content of water supplies. This is also the conclusion of Johns-Manville[25,26], who have been a major supplier to the 320,000 km (200,000 mile) network of water carrying asbestos cement pipe in the United States.

NATURAL SOURCES OF EMISSIONS

The deposits of asbestos, which are of sufficiently high grade for commercial exploitation, represent only a small portion of the total outcroppings. At the present time, asbestos is mined in Vermont, California, and Arizona. The Chicago Natural History Museum exhibits asbestos ore samples from a number of counties throughout the U.S.A., as shown in Table 1. The areas in which asbestos is likely to occur have been surveyed by various government agencies, including the State Department of Natural Resources, the U.S. Bureau of Mines[27], and the Environmental Protection Agency[28]. Their findings are summarized in the map Figure 1.

Chrysotile asbestos is found in serpentine rocks which were formed by the metamorphosis of ultrabasic volcanic rocks. There is a high probability of finding chrysotile asbestos wherever serpentine is found. Even when visible veins are absent, chrysotile is invariably present when the rock is crushed and subjected to close microscopic scrutiny.

Amphibole asbestos in deposits of commercial value are found in metamorphic rocks of sedimentary origin. The common ultramafic rocks of igneous or metamorphic origin are also known to contain asbestiform amphiboles.

Because of their wide occurrence, natural sources could well constitute a major source of asbestos background levels. Activities of man, including farming, land development, and road building could activate the release of fibers and expose surfaces enabling erosion by natural elements to occur. These emissions would be in addition to the emissions occurring from these deposits without man's intervention.

At the present time, there is no reference in the literature which cites the control of natural sources of asbestos emissions.

DUST CONTROL IN ASBESTOS MINING

Introduction

With the exception of the small mines in Arizona, the mining of asbestos in the United States is done by open-pit methods. This type of mining generates large amounts of dust which are difficult to confine. Efforts to prevent asbestos dust from becoming airborne during mining operations are minimal. Dust suppression techniques are employed by

Table 1. A PARTIAL LIST OF ASBESTOS OUTCROPS

Location	State
Clebern County	Alabama
Dahl River Kobek Shanak River	Alaska
Yabapia County	Arizona
Garland County	Arkansas
Duval County	Florida
Oscaloose County Habersham Pine Mr. Mine, Robin County Sall Mt. Sautee	Georgia
Washington County	Idaho
Buchanan County	Iowa
Greenup	Kentucky
New Orleans County	Louisiana
Penobscot	Maine
Blue Mt. Quarry, Baltimore	Maryland
Suffolk County	Massachusetts
Sturgeon Falls Huron County	Michigan
Jackson County	Missouri
Douglass County	Nebraska
Lincoln County Humboldt County	Nevada
Cumberland County	New Jersey

Table 1 (continued). A PARTIAL LIST OF ASBESTOS OUTCROPS

Location	State
Royal John Mine, Grant County	New Mexico
Dutchess County	New York
Vance County Bakersville County Mason County	North Carolina
Cuyahoga	Ohio
Multnomah Adam Gordons Place on Branch Creek, Grant County Josephus County	Oregon
Lazerne County Brintons Quarry, Chester County Easton, E. end of Chustnut Hill	Pennsylvania
Lawrence County	South Dakota
Davidson County	Tennessee
Bexa County	Texas
Weber County	Utah
Blue Ray County Bedford County	Virginia
Berkeley County	W. Virginia
King County	Washington
Albany County Caster Mt., Natrona County Encampment	Wyoming

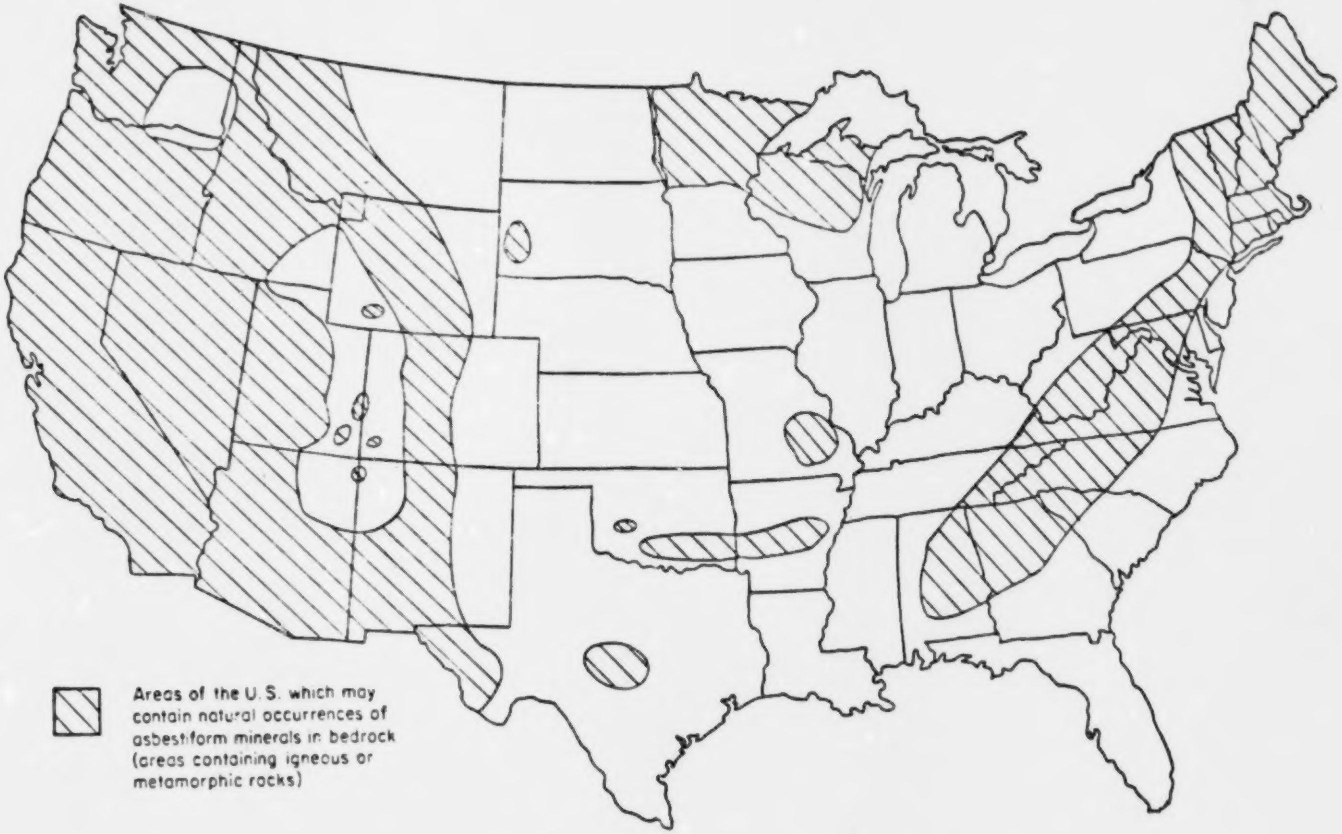

Areas of the U.S. which may contain natural occurrences of asbestiform minerals in bedrock (areas containing igneous or metamorphic rocks)

Figure 1. Possible areas of asbestos deposits
(Taken from Reference 72)

other industries which use open-pit methods. These control methods are applicable to the asbestos mines with little or no modification.

Spraying to Suppress Dusts

The most common method used to control dust in open areas is to spray the surface. The spray may be just water or water containing both organic and inorganic wetting agents, oils, and polymers.

Herod[29] discusses the control techniques used in the lime industry. Sprays from towers are used to control emissions from ore stock piles. Chemical additives are used with the water sprays to bind the top surface of the pile for more lasting emission control. On unpaved roadways, oil sprays are preferred to water, although attention must be given to the odor problem and the possibility of seepage into waterways. On paved roads, vacuum sweeper units are preferred to sprays for the reason that emissions are suppressed only so long as the surface is wet.

Extensive use is made of dry, powdered salts in German mining operations. Externbrink[30] and Reusch[31] describe the use of hygroscopic calcium chloride powders. When these powders are used in underground operations, they have the added advantage of reducing the risk of fire and explosion. In the U.S.A., powdered calcium carbonate and dolomite are frequently used for the same purpose.

Water sprays alone are used extensively. Morse[32] describes the use of sprays in coal mining operations in the U.S. A. MacLeod[33] describes the dust suppression in the mines of British Columbia citing mines containing silica and asbestos as particularly important. MacFadeen[34] refers to the use of water sprays in the coal mines of Sydney, Australia.

Fife[35] discusses the use of water sprays underground. He makes the statement that chemical additives can help to varying degrees. Again, with reference to coal mines, McClung[36] suggests the use of water sprays to reduce dust in U.S.A. mines.

Sprayed foams were exhaustively tested by the British Coal Board. They concluded that foams were too expensive and the application technique lacked simplicity. More recently, Chironis[37] describes the use of a new foam made by the Monsanto Company (Trade name EMA-54). Preliminary tests indicate that this foam is superior to those used previously for dust suppression. It forms a blanket through which the emissions cannot easily penetrate.

Rock Drilling

Explosives are required to dislodge and fragment ore from the deposit. The explosive charge is dropped into a narrow hole drilled into the deposit. Various types of drills are used, including air swept rotary and percussion drills, and water swept drills.

Water or air sweeping serves two functions. Firstly, it carries broken fragments and dust away from the cutting face. Secondly, it reduces the temperature of the drill bit. Air sweeping is more commonly employed in open-pit mines, and its use leads to dust emissions. Water sweeping is more common in underground mines and emissions are kept to a low level by the water, which slurries the dust. Water sweeping is not frequently used in large-scale field operations because of the problems of water supply and water freezing during winter months.

The types of drills and related equipment used have been reviewed by Horsley[38], Shore[39], and Bauer[40].

Grossmueck[41] describes the use of cyclone and baghouse collectors on air flushed drills. On water swept units, he discusses the use of wetting agents to improve the efficiency of the wetting. Lewis[42] describes the use of foam-type dust suppressors, which are claimed to be more efficient than water alone. A new type of drill, which uses a high velocity water jet instead of a conventional drill, is described by Chironos[43] . It is claimed to be fast, dustless, explosion proof, and economical in use.

Hutcheson[44] reviewed the measures taken by the Quebec asbestos industry to control dust emissions. The extreme cold of the Canadian winters make the use of water drills impossible. Experiments have been conducted on the use of fuel oil instead of water. However, fuel oil causes an obnoxious odor and contaminates the soil.

A satisfactory solution to the dust problems associated with percussion primary drills is an envelope-type bag filter; it is compact and suitable for carrying on the crawler frame. Power for operating the fan can be provided by an air motor where no other means is available. The bags are made of silicate-treated nylon acetate; they shed the dust easily and dry quickly if water is accidentally drawn into the filter. (Figure 2 shows the diagrammatical arrangement on a crawler drill.) Drilling by large rotary drills is performed through a platform, and the platform itself serves as the top of the hood. The sides of the hood are formed with rubber aprons (Figure 3). The end apron is hinged; this enables it to be raised when the machine is being moved; thus, preventing the chips and dust from being dragged back into the hole. The enclosure thus formed acts as a settling chamber so that no chips are drawn up into the bag filter. The dust shaken out of the filter is discharged into this bottom

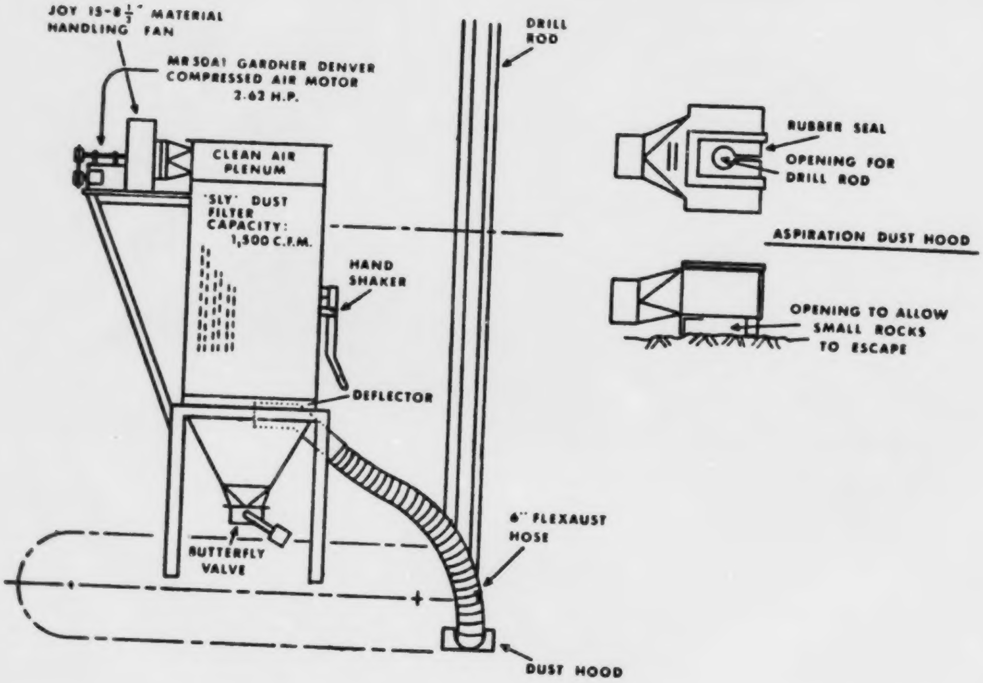

JOY 15-8½" MATERIAL HANDLING FAN
MR50A1 GARDNER DENVER COMPRESSED AIR MOTOR 2.62 H.P.
CLEAN AIR PLENUM
'SLY' DUST FILTER CAPACITY: 1,500 C.F.M.
HAND SHAKER
DEFLECTOR
BUTTERFLY VALVE
DRILL ROD
RUBBER SEAL
OPENING FOR DRILL ROD
ASPIRATION DUST HOOD
OPENING TO ALLOW SMALL ROCKS TO ESCAPE
6" FLEXAUST HOSE
DUST HOOD

Figure 2. Dust control for the Gardner Denver PR-143 Impact Drill

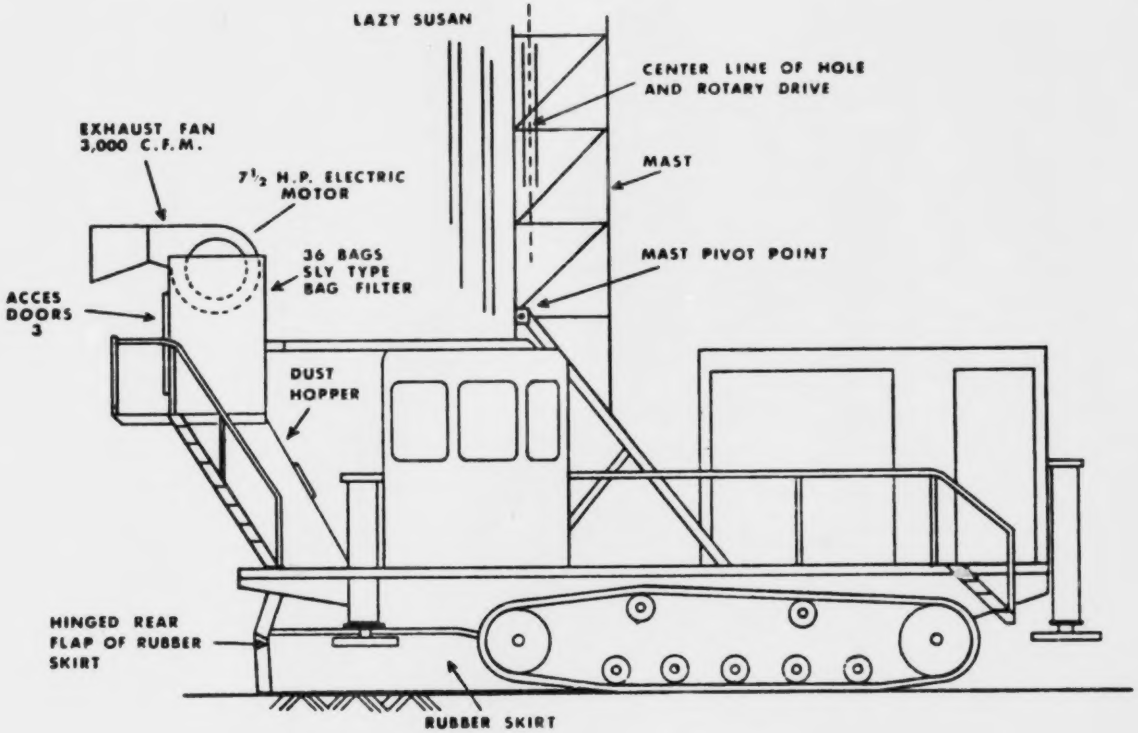

LAZY SUSAN
CENTER LINE OF HOLE AND ROTARY DRIVE
EXHAUST FAN 3,000 C.F.M.
7½ H.P. ELECTRIC MOTOR
MAST
36 BAGS SLY TYPE BAG FILTER
MAST PIVOT POINT
ACCES DOORS 3
DUST HOPPER
HINGED REAR FLAP OF RUBBER SKIRT
RUBBER SKIRT

Figure 3. Dust control for the Bucyrus Erie 40-R Rotary Drill

enclosure; thus, substantially reducing the dust emission during the filter-emptying operation.

Whenever possible, drilling of mine heads and the large boulders that require secondary blasting is now done by a mobile drill equipped with a bag filter; the filter is cleaned automatically by compressed-air pulses (Figure 4).

Table 2 summarizes the typical primary and secondary drilling units together with the capacity of dust filtering devices used.

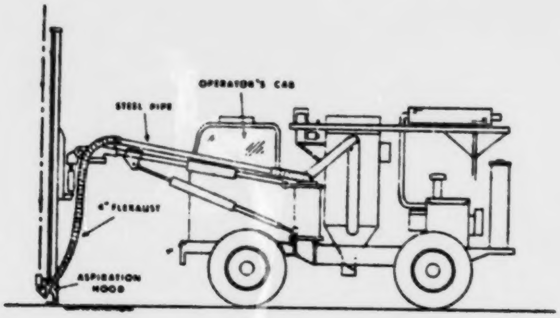
It is concluded[44] that the bag filter offers the best type of dust control for open-pit drilling. It offers good environmental control with the ruggedness necessary for the severe conditions encountered in this type of operation.

Blasting Operations

Emissions are created by blasting due to fragmentation and to disturbances of the surrounding area by shock waves. The emissions are particularly noticeable because large numbers are released over a very short period of time, by the large fragments also released, and by the associated noise.

The rate at which the explosion proceeds has a demonstratable effect on the nature of the fragmentation. The shattering of rock by an explosion is referred to as brisance. High brisance explosives proceed rapidly and have a high shock energy and low impulse. Conversely, low brisance explosives have more impulse and less shock energy. They have more general utility in mine blasting since they will loosen large sections of rock without fragmenting. They are environmentally attractive because the dust cloud is very much reduced.

Lang[45] analyzed the means by which explosive energy is utilized in the breakage process. He finds there are three


OPERATOR'S CAB
STEEL PIPE
4" FLEXAUST
ASPIRATION HOOD

DUST FILTER — "Mikro Pulsaire" bin vent Model BIN 4A HCE dacron felt bags, solenoid valve and timer kit. Mounted in housing by C.I.M.

FAN — Industrial exthaust, 500 cfm at 11 in. SP and 5,000 rpm.

MOTOR — Gardner Denver type. Heavy-Duty non-geared, MR 30A 1.

Figure 4. Dust control for the Gardner Denver secondary drill

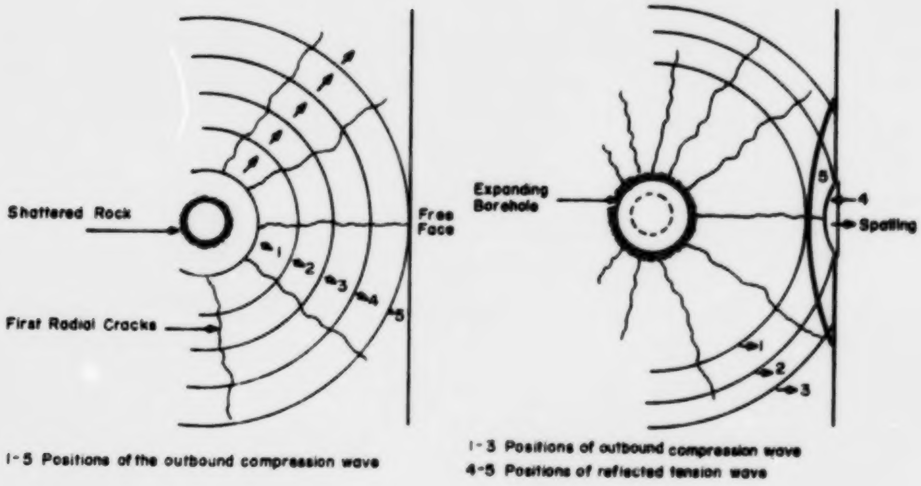
Table 2. DRILL AND DUST COLLECTION DATA

Unit	Drill Hole Diameter cm (in.)	Filter Flowrate lpm (cfm)	Type of Fan Drive
Percussion drill, Gardner Denver PR-143	15.2 (4.0)	42,500 (1,500)	6.2×10^5 N/m^2 (90 psi) Compressed air
Rotary drill, Gardner Denver RDc 30	17.1 (6.75)	56,600 (2,000)	Hydraulic
Rotary drill, Bucyrus Erie 40-R	17.1 (6.75)	85,000 (3,000)	Electric
Secondary drill, Gardner Denver MR 30A1	6.4 (2.5)	14,200 (500)	6.2×10^5 N/m^2 (90 psi) Compressed air

distinct stages as illustrated in Figure 5. In the first and second stages, the function of the shock wave energy is to condition the rock by inducing numerous small fractures. In most explosives, the shock wave energy amounts to only 5 to 15% of the total energy of the explosive. It is probable, therefore, that the shock serves to condition the rock for the final breaking stage.

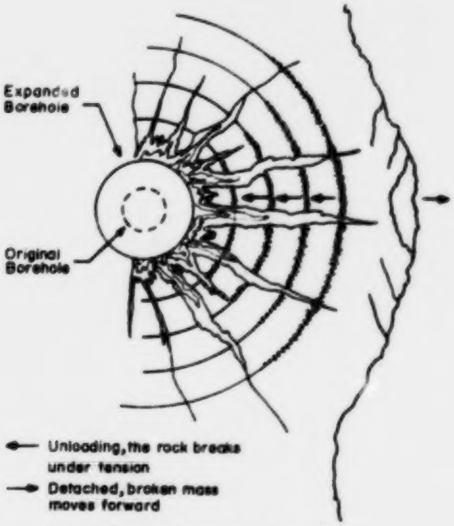
The methods to achieve optimum blasting conditions are being actively researched in Europe, the U.S.S.R., as well as the U.S.A. The research is directed more towards developing efficient rock removal than reducing emissions. However, the two events usually occur in combination. Several new explosives are currently being researched to achieve these ends, they include: 1) coating ammonium nitrate granules with suitable high explosives such as nitroglycerine, 2) use of aluminized explosives to extend the reaction zone, 3) slurry-type oil and explosive mixtures, and 4) foam-type explosives which can be "foamed" in-situ to produce an explosive making intimate contact with the walls of the bore hole.

Lang also discusses the use of multiple-hole blasting; here a series of smaller charges have the effect of lifting and freeing a section of the rock face. To be effective, a reflecting plane or free face is provided in front of each blast hole in order to precondition the mass within the geometry, detach it, and displace it horizontally. This is done by systematically delaying the sequence of detonation of blast holes or groups of blast holes away from the point of initiation. The time interval between the detonation and the beginning of mass motion is 5 to 10 times the shock wave travel time from the blast hole to the free face. The net result is a marked reduction in fragmentation and in dust emissions.


Shattered Rock
First Radial Cracks
Free Face
1
2
3
4
5
1-5 Positions of the outbound compression wave
Expanding Borehole
5
4
Spalling
1
2
3
1-3 Positions of outbound compression wave
4-5 Positions of reflected tension wave

(a) Plan view of Stage 1

(b) Plan view of Stage 2


Expanded Borehole
Original Borehole
Unloading, the rock breaks under tension
Detached, broken mass moves forward

(c) Plan view of Stage 3

Figure 5. Explosion breakage process

Grossmuech[41] has reported on the practice of stemming the blast holes with cartridges made of polyvinylchloride or polyethylene. The cartridges or ampoules are of various shapes about 30.5 cm (12 in.) long and contain 300 cc of water with or without wetting agents. Reportedly, dust concentrations are reduced by 20 to 80%.

Water spraying is a control technique very generally used. It will restrict dust emissions from surrounding surfaces during blasting, but cannot reduce the emissions due to fragmentation from the blast hold itself. A ventilator sprinkler was described by a Russian[46], Filatov, in 1973. This device, shown in Figure 6, consists of an engine based on that used to power the TU-114 airplane; water can be added to the air stream. Open mine areas up to 200 by 300 m in depth have been ventilated by these units. At a water consumption of 180 m^3/hr, the solid content of the air is reduced from 8.4 mg/m^3 to 2.4 mg/m^3 in 28 minutes. After 15 minutes, it had dropped to 3.5 mg/m^3.

Ore Dumping

Emissions are created when ore is dumped at the ore crusher. The measures that are taken to reduce these emissions in most mining operations consists of erecting an enclosure over the dumping pit and fitting an extractor hood over the crusher itself. The typical arrangement of the hooded crusher is shown in Figure 7. This unit, described by Hutcheson[44], is fitted to the Canadian asbestos mines of Johns-Manville. It is estimated that a 121.9 x 152.4 cm (50 x 60 in.) jaw crusher requires 8.5 x 10^4 lpm (3,000 cfm) of air for this purpose.

Randveer[47] describes the use of air curtains formed by the use of tengential air blowers. No details were given on the efficiency of such an arrangement.

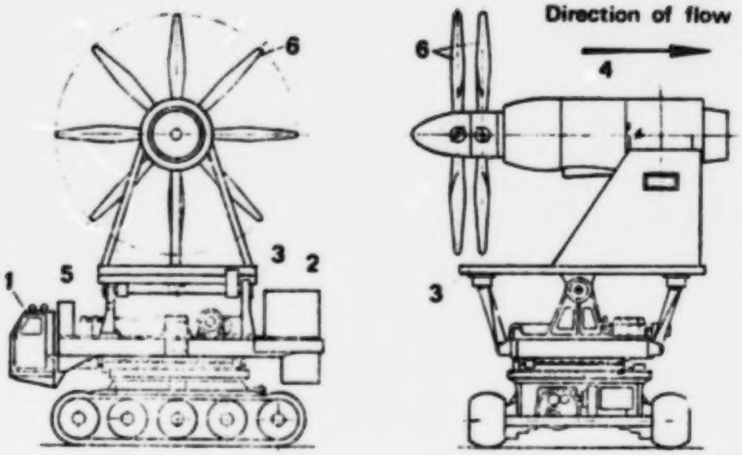

6
1
5
3
2
Direction of flow
6
4
3

Figure 6. The ventilator sprinkler

Key:

1. Operators cabin
2. Fuel tank
3. Power unit platform
4. Power unit
5. Bearings for platform
6. Two four bladed contra-rotating propellers

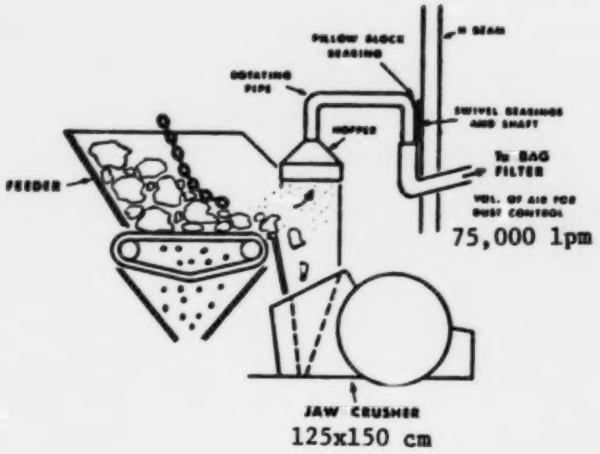

H BEAM
PILLOW BLOCK BEARING
ROTATING PIPE
SWIVEL BEARINGS AND SHAFT
HOPPER
To BAG FILTER
FEEDER
VOL. OF AIR FOR DUST CONTROL
75,000 lpm
JAW CRUSHER
125x150 cm

Figure 7. Dust control for the jaw crusher

Loading and Hauling

Loading and unloading ore from trucks, and the hauling of ore by trucks on roadways, are all actions which can give rise to emissions. These activities are common to many industries; the methods of reducing these emissions are obvious, but seldom practiced. Loading and unloading may be carried out in ventilated, emission controlled enclosures. At the least, fine spray water jets can be directed onto the dust cloud at the source. Emissions from ore as it jostles in trucks may be eliminated quite simply by enclosing the load. Currently, the loads in mining operations are completely uncovered. When trucks travel on public roadways, the loads are covered by ill-fitting tarpaulins that do little to curb emissions.

Roadways within the mine area are frequently composed of crushed ore bearing rock. Under dry conditions, considerable emissions are created as vehicles traverse the area. These emissions may be drastically reduced by spraying the roadways either with water, or, for better, longer lasting protection, with polymers, lignin sulfates, or bitumen compounds[47,48]. On paved roadways, the use of vacuum sweepers has been recommended as a superior approach[29].

DUST CONTROL OF ORE STORAGE AND WASTE DUMP AREAS

Introduction

At asbestos mines and milling plants, raw ore is stored, and at asbestos processing and mills, waste material is dumped. These areas constitute very large open area sources of asbestos emissions.

Ore Storage Piles

Milling is a continuous operation and, in many instances, it is carried out 24 hours per day, seven days a week. Ore is stored in piles near the mill to ensure that an uninterrupted flow in achieved through the mill. In this way, problems in mining, such as weather, equipment failure, etc., are largely eliminated.

The ore pile, which is rich in asbestos, is an important source of emissions when ore is being added and removed. Control of emissions is difficult because the pile is usually too large to cover. In addition, operators do not generally like to wet the pile since this adds to the processing costs.

Even so, wetting and the strategic deployment of wind breaks constitute the only reasonable methods of control at this time. The use of foam dust suppressors with chemical stabilizers is an attractive alternate for the future, since they contain very little water.

Asbestos Mill Tailings Dumps

Typically, the ore processed at the GAF mill in Vermont contains 4 to 5% asbestos by weight. The waste rock, which has asbestos clinging to it, is transported to the tailings piles. The only controls applied are the use of covered conveyors for the tailings transport, enclosure of the conveyor connection points, and a semi-enclosed spout through which the tailings are added to the pile. The tailings are subsequently graded to maintain the slope stability of the piles.

No efforts are made to reduce emissions from the piles by vegetation or chemical stabilizers.

Asbestos Products Manufacturing Waste Dumps

The scraps, rejects, and other wastes from an asbestos manufacturing process are usually dumped on a waste pile near the plant. The operations of the dump and its uncontrolled exposure to the elements are sources of emission. The trucks which carry the waste to the dump are uncovered. The tipping of the trucks, the grading and crushing of the pile by bulldozers create emissions which are also uncontrolled.

The covering of the inactive portions of the dump with soil and the planting of grass is being tried at the Johns-Manville plant in Waukegan, Illinois. It is too early to draw even tentative conclusions on its effectiveness. Chemical stabilization has not been tried. The typical dump is left untreated.

The Erosion by Wind

The erosion of soil from the land has been studied for many years. It was stimulated by agricultural disasters whereby huge tracts of prime agricultural lands were denuded by very strong winds. Unfortunately, most of these studies are concerned with light tillable soils rather than rock fragments or ultra-fine fibrous particles. Such studies as these conducted by Bagnold[49], Fly[50], Daniel[51], and Chepil[52] are concerned with the grading of sands and arable soils.

In terms of this study, the most significant point is that the erosion can be extremely extensive. Finer materials are preferrentially removed and carried large distances. The smaller the particle, the greater the transport distance (Chepil[53]).

Woodruff[54], following earlier work of Chepil, has developed the following mathematical expression to describe erosion:

$$E = f(I', K', C', L', V)$$

where E = amount of erosion

I' = soil and knoll erodibility index

K' = soil ridge roughness factor

C' = local wind erosion climatic factor

L' = field length along the erosion direction prevailing wind

V = equivalent quantity of vegetative cover

The process of wind erosion is extremely complex and the above equation condenses 11 primary variables known to affect wind erosion into the five stated equivalent variables. The purpose of the equation is to provide a tool by means of which 1) the erosion from an area may be determined, and 2) the field conditions of soil cloddiness, roughness, vegetative cover, physical barriers and width, and orientation may be determined to reduce erosion to a minimum.

The theory as it presently stands has many practical weaknesses, mainly because of the number of variables which interrelate in such a complex manner. The theory was developed from laboratory experiments conducted in wind tunnels. Woodruff[55] used a wind tunnel to investigate the use of wind breaks to reduce erosion. Zingg[56] investigated the erosion of sedimentary deposits using a wind tunnel. The calibration of a wind tunnel for the simple determination of roughness and drag on field surfaces is reported by Zingg[57].

The conclusion is reached that the use of mathematical analysis might be improved upon[58], and the theory made more accessible through the use of computers (Skidmore[59]). The use of a wind tunnel is the only method available of obtaining direct data applicable to a given particular situation.

The whole subject of the stability of land masses subjected to changes produced by both man and nature is discussed comprehensively in a book by Beasley[60]. Chapter 3, which deals with the subject of wind erosion, serves as an excellent introduction to the subject. The factors which lead to high surface erosion may be listed as:

- the surface is dry, loose, and finely divided
- the surface is smooth
- there is a lack of vegetation cover
- no physical barriers are present over a wide area
- strong winds are blowing

Any steps which will reduce these factors will reduce emissions.

Stabilizing Mine Dumps

The most satisfactory method of stabilizing a dump area is a vegetative covering. This has the combined merits of providing a lasting protective cover and being aesthetically pleasing to the observer. Unfortunately, mine dumps are frequently difficult to vegetate because the wastes are sterile, contain deletrious inorganic salts, and lack the essential nutrients and physical characteristics required for sustaining vegetative growth.

In recent years, mine waste stabilization has been studied more actively because of safety[61] following the disastrous slope failure of a dump in Great Britain. Also, in many countries, the air pollution threat has encouraged the spending of considerable sums of money to stabilize dumps, as for example, in the gold mine waste dumps of South Africa[62]. An article by James[63] describes the efforts that led to the successful stabilization of mine dumps by vegetative covering. An area of 101 km^2 (25,000 acres) was stabilized despite conditions where the pH could reach 1.5 due to oxidation of pyrites. It was found that adding lime was insufficient and costly. A better method was to trickle water through the surface, washing the acid away.

The efforts to stabilize copper mine tailings from the Pima mine in Arizona were reported recently by Ludeke[64]. A 0.34 km^2 (85 acre) tract has been treated. The tailings lacked humus, nutrients, moisture, bacteria, and microorganisms essential to sustain plant life. A mulch made from hay or barley straw provided the above and, in addition, insulated the surface and reduced rain erosion.

Hydroseeding is a most efficient way to cover a surface. It provides vegetative, physical, and chemical stabilization all at the same time. In hydroseeding, a slurry is prepared from a resinous adhesive-soil seal, wood fibers, fertilizer, seeds, and water. This is sprayed directly onto the slopes. A two man team could treat 0.02 to 0.04 km^2 (5 to 10 acres) per day. This contrasts with 6 to 8 men taking several weeks to stabilize a surface by hand. The cost of the above procedure is shown in Table 3.

Considerable amount of work on soil stabilization has been undertaken by Dean and his co-workers at the United States Bureau of Mines[65,66,67,68]. In a study to investigate the stabilization of copper mill tailings in Nevada, they attempted physical, chemical, and vegetative stabilization.

Physical means of stabilization included:

- water spray
- soil and crushed rock -- allows vegetation
- crushed or granulated smelter on inactive tailings ponds -- does not allow vegetation
- bark
- straw
- windbreaks and vegetation in combination
- limestone and sodium silicate

Table 3. CHEMICAL-VEGETATIVE HYDROSEEDING COSTS FOR TREATING A PLOT OF 4,047 m^2 (ONE ACRE)

Item	Rate of Usage	Cost
Seeds	41 g/m^2 (75 lb/acre)	$ 287
Fertilizer	30 g/m^2 (55 lb/acre)	16
Wood fiber	815 g/m^2 (1,500 lb/acre)	70
Hydroseeder	Seeding of 4,047 m^2 (1 acre)	150
Soil seal	87 cc/m^2 (80 gal/acre)	387
Labor @ $4.00 per hour	3 men for 3 days	288
Water truck	Water supply for seeder	100
	TOTAL	$1,298/acre or $0.32/$m^2$

Chemical means of stabilization included:

- Coherex, a resinous substance -- cost 1.2¢/m^2 (\$0.01 per sq yd)
- calcium, ammonium, and sodium lignin sulfonates -- cost 2.4¢/m^2 (\$0.02 per sq. yd)
- cement and milk of lime -- cost 3.6¢/m^2 (\$0.03 per sq yd)
- Paracol S 1461 -- a blend of wax and resin -- and Paracol TC 1842 -- a resin emulsion -- cost 4.8¢ to 12¢/m^2 (\$0.04 to \$0.10 per sq yd)
- cationic neoprene emulsion and Rezosol, an organic polymer -- cost 9.5¢/m^2 (\$0.08 per sq yd)
- sodium silicates with ratios of 2.4 to 2.9:1 SiO_2 to Na_2O when applied in quantities of 11.8 kg/m^2 (4.5 lb per sq yd) and at a cost of 13¢/m^2 (\$0.11 per sq yd) were effective. Calcium chloride was an effective additive to the silicates whereas ferrous sulfate was not. The addition of 6% by weight to the sodium silicates reduced the cost from 13¢ to 2.3¢/m^2 (\$0.11 to \$0.02 per sq yd)
- peneprime (a bituminous based compound), compound SP-400, soil guard, and DCA-70 compound -- cost 11.9¢/m^2 (\$0.10 per sq yd)
- pyrite, aerospray binder 52 (synthetic resin), landscape (sulfur in water soluble oil), water mate (an organic non-ionic product, cellulose, lactose, and starch -- all found to be non-effective.

All of the above methods of stabilization were tested both indoor and outdoor under laboratory conditions. The effects of wind, rain, snow, and temperature extremes were studied. Air and water jets were directed onto the surface to simulate natural conditions. The coherence of the surface was then tested. From the results of the laboratory tests, two chemical treatments were selected for field testing. They were:

(a) DCA-70 -- an elastomeric polymer from Union Carbide. Used at a strength of 4%, it costs 11.9¢/m^2 (\$0.10 per sq yd) to cover; 0.026 km^2 (6.5 acres) of ground required 6,600 ℓ (1,500 gal)

(b) calcium lignosulfonate applied to a tailings pond area, needed 2.75 kg/m^2 (1.05 lb per sq yd) on the 0.11 km^2 (28 acre) site or 4.5¢/m^2 ($0.0375 per sq yd)

It was found that vegetative coverings were possible if a 15.2 cm (6 in.) layer of soil was first placed on the dump. Multi-species plants were sown until information became available on the correct seeds to sow. A trial 0.04 km^2 (10 acre) plot was treated using a combination of chemical and vegetative stabilization. A record of the costs was maintained, and they are given in Table 4.

The problem of coal mine tailings piles in the east Kentucky area has been studied by Cummins[69]. He showed that by studying the chemistry, pH, and climate of an area, plants may be selected which will grow on these dumps. Asbestos tailings have received very little attention. Hutcheson[44] has described the efforts of the Quebec Asbestos Mining Association Research Laboratories in Sherbrooke, Quebec. The problem they had to overcome was that serpentine rock is highly alkaline, having a pH of about 9.0. It was found necessary to mix the tailings with acidic copper mine tailings before growth could be sustained.

OPEN-AIR OPERATIONS INVOLVING ASBESTOS PRODUCTS

Introduction

As a consequence of its wide useage and utility of asbestos products, literally hundreds of uses are found for asbestos in open-air operations. The major user of asbestos in open-air locations is the construction industry. Formerly, the most obvious offender in terms of visible asbestos emissions was the spraying of asbestos insulation. Since this practice has now been banned, insulation stripping and the field fabrication of insulation products are the two major areas of asbestos emissions at the present time.

Table 4. COST OF STABILIZATION PER 0.04 km^2 (10 ACRE) PLOT

Item	Application Rate	Cost
Seeds	398 seeds/m^2 (37 seeds/ft^2)	$ 56
Calcium treble Superphosphate	24.5 g/m^2 (45 lb/acre) P_2O_5	51
Prilled urea	24.5 g/m^2 (45 lb/acre) N	62
Coherex: at 1.4¢/ℓ (20¢/gal) freight at 0.5¢/ℓ (8¢/gal)	5.2 ℓ/m^2 (0.18 gal/yd^2)*	348 140
Labor at $3.00/hr	3 men for 3 days	216
Equipment expenses: seeder and grader water truck	water to depth of 6 mm (¼ in.) and to apply chemicals	382
	TOTAL	$1,255
	UNIT COST	3.10¢/m^2 ($125.50/acre)

* Coherex solution diluted with four parts by volume of water.

Stripping of Asbestos Insulation

Asbestos containing products are used as insulation to pipes, boilers, ceilings, and building super-structures. In many instances, the insulation was applied as a sprayed-on cement slurry.

Remodelling, refabrication, and demolition leads to emission of asbestos. The methods which can be used to reduce these demolition emissions have become part of the building and construction codes of many large cities. A well written set of recommendations are those described in the handbook of the Asbestos Research Council[70]. Methods described include isolation where possible, the use of water sprays, total saturation of the insulation, and the use of disposable sheeting and vacuum cleaners.

Field Fabrication of Asbestos Products

A large number of asbestos containing products are used in the construction industry. They are sanded, cut, and drilled in open conditions on building sites.

The types of materials include the following:

Preformed asbestos selections or blocks containing materials which, by nature, are very dusty are used for insulating pipes and/or boilers. These applications may be used for either hot or cold temperature extremes. Examples include:

- molded asbestos
- molded calcium silicate/asbestos
- molded magnesia (85%)
- molded high temperature insulating block

Another group is the materials which are applied in a wet or slurry state. Frequently, these materials are used to seal joints between the blocks or sections discussed in the previous group. When used this way, their composition is similar to the material being sealed and they are mixed with water just prior to use. Examples are:

- calcium silicate asbestos cement
- 85% magnesia
- hard-setting asbestos cement
- asbestos skinning plaster

A third group of asbestos materials consist of the asbestos cement products. These products have sealed surfaces which will not dust easily. Considerable energy is required to cut, drill, or break these products. Examples include:

- roofing shingles
- building boards
- drain pipes

Finally, there is a group in which asbestos constitutes a large percentage of the material. Generally, the asbestos fibers are loosely bound and the material does not possess a predetermined shape. Examples include:

- asbestos paper
- asbestos blanket or clothing
- asbestos rope, tape, yarn, and sealing compounds

Emissions which are created during field fabrication of asbestos containing materials will vary as to: type of material being fabricated; the amount of fabrication required (cutting, sawing, sanding, etc.); the location and nature of the fabrication site; and the quantity of material to be fabricated. The form that the asbestos is in will have an obvious effect on emissions. Free powdery materials or materials in which the fibers are loosely bound will be more prone to emission than those in tightly bonded composites.

Emissions during fabrication will vary according to the amount of cutting, drilling, or sanding required. To reduce emissions, the various fabricating tools may be fitted with attachments such that the dust created is arrested at the source and collected in filter bags. Commercial devices are available. Two examples of such devices are shown in Figures 8 and 9. The hoods work on the high velocity, low volume principle and can be readily adapted to industrial vacuum cleaner systems.

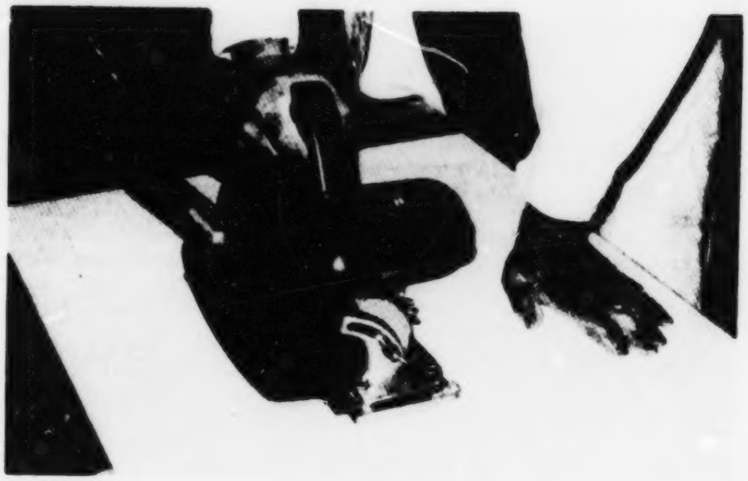


Figure 8. An electric portable saw with shroud for fitting to exhaust ventilation unit

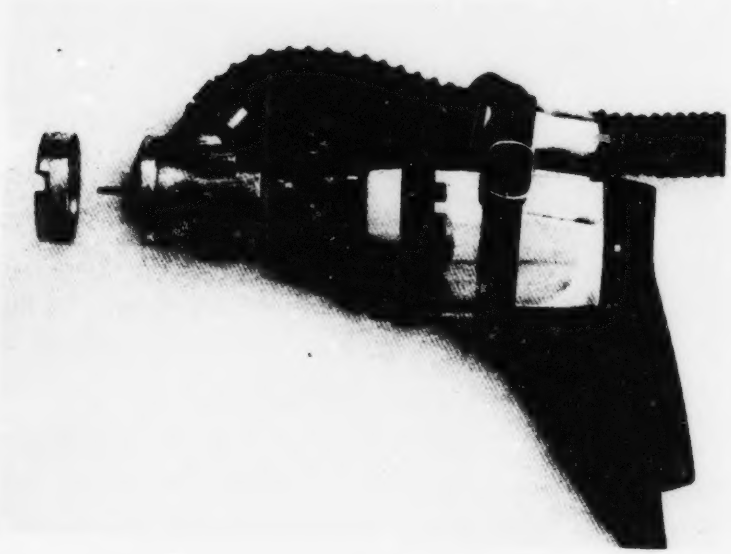


Figure 9. A portable hand drill suitable for use with exhaust ventilation units

SECTION 5

SITE SURVEYS

INTRODUCTION

The asbestos mines and mills operating in the United States are listed in the accompanying Table 5. All except the Powhatton mine in North Carolina produce chrysotile asbestos. In total, the mines produce approximately 15% of the asbestos used in the United States. The remainder is imported, mostly from Canada.

The largest single U.S. mine is the GAF mine located in Vermont. The ore is similar to that mined much more extensevely in Canada and is an outcrop of the same massive ore body. The company claims that they will cease operating in 1975 because it will not be economically feasible to meet EPA emission limitations.

California is the largest producer of asbestos by state. The largest mine, the Pacific, produces the normal long fibered form of chrysotile asbestos. Three mines, the Coalinga, Atlas, and Union Carbide, are in close proximity to each other near Coalinga. They work an ore body which is 16 km (10 miles) long and 0.4 km (¼ mile) wide. The ore from these mines is atypical of asbestos. Instead of a fibrous vein structure, the asbestos is in a platy, slippery form; it is known locally as desert leather.

The Union Carbide company trucks its ore 112 km (70 miles) to King City for milling. They wet mill, a process

Table 5. THE UNITED STATES ASBESTOS MINES

Operating Company	Location and Number of Employees				Approximate Weight of Asbestos Produced per Day (metric tons)
	Mine	Employees	Mill	Employees	
GAF	Hyde Park, Vt.	58	Hyde Park, Vt.	143	200*
Coalinga Asbestos Co. Div. of Johns-Manville Corp.	Coalinga, Calif.	20	Coalinga, Calif.	50	100*
Atlas Asbestos Corp.	Coalinga, Calif.	20	Coalinga, Calif.	50	100
Union Carbide	Coalinga, Calif.	36	King City, Calif.	50	100
Pacific Asbestos Corp.	Copperopolis, Calif.	36	Copperopolis, Calif.	135	200*
Powhatton Mining Co.	Burnsville, N.C.	4	Baltimore, Md.	8	Operations Suspended
Jacquays Mining Corp.	Globe, Ariz.	8	Globe, Ariz.	5	10
Asbestos Mfg. Co.	Globe, Ariz.		Globe, Ariz.		Operations Suspended *
Metate Asbestos Co.	Globe, Ariz.		Globe, Ariz.		Operations Suspended

N.B. 1. All mines open pit except those in Arizona, which are underground.

2. All produce chrysotile asbestos except Burnsville, N.C., which produces anthophyllite.

* Mines having the stated intention to close by the end of 1975.

which is unique in the asbestos industry. The other companies, Atlas and Coalinga, built mills which were essentially scaled down versions of normal asbestos mills. They use air aspiration to separate fibers from crushed rock. The very short fiber from these deposits is not really suited to air aspiration methods. The Union Carbide can wet mill because water is plentiful in King City; water is scarce in Coalinga.

Johns-Manville announced that they will be shutting down their Coalinga asbestos mine and mill in 1974 because it is not economically feasible to meet EPA emission control requirements. The Pacific Asbestos Corporation has also announced the shutdown of their operations near Copperopolis citing EPA restrictions as the reason.

Arizona produces small quantities of an exceptionally pure form of high quality chrysotile asbestos. It is low in iron and is suitable for electrical insulation and filter manufacture. Large quantities are exported to Japan. Mining is carried out underground, largely by casual, unskilled Indian labor. The ore is freed by drilling and explosion. It is hand cobbed (beneficiated) using a hammer and the enriched ore is transported to the mill by truck. Of the three mines in the Globe area, only one, the Jacquays mine, is currently in operation. Another, the Metate Asbestos Company, has announced the redevelopment of their property into a mobile home park.

A small quantity of anthophyllite has been mined by open pit methods in Burnsville, North Carolina. The ore is trucked to Baltimore, Maryland, where it is milled. The operation was closed down at the time of this survey. Reportedly, the efforts to control emissions from this operation were very limited.

SURVEY LOCATIONS

As part of this study, visits were made to three locations to observe the operation and the control techniques used. The GAF mine in Vermont was visited because it represents the largest single mining and milling operation in the United States. The Coalinga mine of Johns-Manville was visited because the chrysotile asbestos mined at that site is a most unusual short fibered variety. The Atlas and Union Carbide operations, which mine the same type of asbestos, were observed from outside their plant boundaries. The Pacific Asbestos Company denied a request for a visit. The facilities were viewed from outside the plant. The Union Carbide mill in King City, California, was surveyed because it has the unique distinction of utilizing a wet-mill process for asbestos.

A visit was planned to survey the Burnsville, North Carolina, mine belonging to the Powhatton Mining Company. This mine, although small, is unique to the United States in that anthophyllite is mined. The visit was not made because the operation was shut down.

The Globe, Arizona, operations were not visited formally because two of the three mines were closed. The third, although the largest of the three, is still very small and the location is very remote. It was not considered to be worth the time and cost of a visit. A member of the IITRI staff who happened to pass the area while on vacation, photographed the exposed piles of ore and tailings at the mill site.

THE COALINGA ASBESTOS CO., INC., COALINGA, CALIFORNIA

Date: September 18, 1973

General

The mine and mill is owned by the Johns-Manville organization. It is managed by Mr. Keith Jones. The postal address is Coalinga Asbestos Co., Inc., P.O. Box 1045, Coalinga, California 93210. The telephone number is 209/935-0226. Permission to visit the mine was arranged through Mr. Ed Fenner, Director of Environmental Control, and Mr. W. Van Derbeek, Vice President, both of Johns-Manville at Greenwood Plaza, Denver, Colorado 80217. Telephone 303/770-1000.

The nearest airport to the mine is Fresno, California. Coalinga lies 112 km (70 miles) southwest on Route 198; its population is 7,000. The address of the company office is 505 West Elm Street on the southwest side of the town. The mine is located on private property 22.4 km (14 miles) to the northwest of Coalinga. From Coalinga, taken Derrick Road north to Los Gatos Road. The mine entrance is on the right about 9.6 km (6 miles) from town.

The asbestos deposits form an ore body which is 16 km (10 miles long and 0.4 km (¼ mile) wide. Three companies presently work this deposit: Coalinga Asbestos, Atlas, and Union Carbide. The mines are at an elevation of about 1,220 m (4,000 ft). Coalinga and Atlas have locally situated mills at an elevation of about 914 m (3,000 ft). Union Carbide trucks its ore to King City, some 112 km away (70 miles).

Mining Operations

The asbestos ore occurs at the surface and is very soft and friable. It is only necessary to bulldoze it out and shovel it into trucks. Blasting is carried out a few times a year to remove large boulders which obstruct mining operations. An initial size classification step is carried out at the mine by screening the ore through an unenclosed 10 cm (4 in.) grizzle screen. The ore is then transported to the mill in 45.3 metric ton (50 short ton) trucks.

Mining is carried out during the summer months, the mine is closed from November to April. During the summer, some 18,149 metric tons (20,000 short tons) are mined per day and stock piled near the mill. Snow is never a problem, but heavy rains during the winter make the narrow winding roads treacherously slippery. Approximately 70 workers are employed in the mining and milling operations.

Emission Control at the Mine

There is no attempt to control emissions at the mine. No sprinkling is undertaken, although it should be stated that the ore has high water retention properties. Fresh ore is wet to the touch and contains 30% water. Dried ore at the surface is, however, quite dusty.

Milling Operations

The milling operation, opened in 1962, is a scaled down version of the large mills in Canada. The ore is repeatedly crushed, fiberized, screened, and air aspirated. Before entering the screening system, the ore is coarse screened on a 2.5 cm (1 in.) rotary trommel and then dried through a rotary drier.

The drying air is heated by fuel oil to 677° C (1,250° F) and the exiting gases are 132° C (270° F). The dried ore is again screened through a 6 mm (¼ in.) mesh before entering the milling process. Fiber is collected by air aspiration. It is graded as a function of the fiber length, which is a function of the amount of crushing to which the ore has been subjected. All of the material which passes the 6 mm (¼ in.) screen after the drier is marketable. Even the material collected in the baghouses can be used as a filler. Pressure packing machines are used to fill both polyethylene and paper bags with the product.

Emission Control at the Mill

Considerable efforts are exerted to reduce the emissions of asbestos caused by the milling operations; however, there is still a need for improvement. The ore stock pile covers an area approximately 100 m (90 yd) square. A bulldozer is employed to push the material forward and keep it level. This operation creates a considerable dust cloud. The pile is not wetted by a sprinkler. A dumper truck takes ore from the stock pile to a hopper which feeds the conveyer and rotary screen. None of these operations are enclosed and the ore is not watered-down. The exhaust gases from the drier are fed into a 4-cyclone system. It is plainly inadequate since considerable visible emissions are observed from the stack.

Inside the plant, efforts have been made to totally enclose the screening, crushing, fiberizing, and conveying systems. These are largely effective, but there is still considerable dust in the general plant environment. Some internal vacuum points are installed to help the housekeeping. These are connected to the control exhaust system. The fiber bagging area is particularly dusty. At this point, fiber is emitted into the air. No attempt is made to isolate or enclose this dusty operation. Air from both the fiber aspiration system and from the enclosed units is fed to a baghouse system of 9.9×10^5 lpm (35,000 cfm) capacity. The exhaust system keeps the building under slight negative pressure. No emissions are visible from this unit.

Tailings are carried via a semi-enclosed (hooded) conveyor to the tailings pile. This pile is slowly filling the V of a valley and extends for about 300 m (275 yd) and is about 100 m (90 yd) wide. The material is dumped via an inverted funnel device. However, the operation is still very dusty and large clouds of dust are observed.

Efforts have recently been started to grow leguminous plants on the tailings pile. The results are encouraging, but they are merely test patches at this time.

Comments

The mine and mill are both large sources of emissions at this time. By visual inspection, the most pressing problems are the mining operations, the roadways, the ore dumps, the drier emissions, and the tailings dump. Even though the emissions are obviously large, the mine and mill are in a very remote location. Thus, the cost of control may be substantial and without a significant non-occupational exposure health benefit. The transport of the emissions to centers of population should be determined by a study.

Atlas and Union Carbide Operations

In the same local area as the Coalinga Company mine are the mines of the Atlas and Union Carbide companies. Their operations were viewed from the hills a short distance away; entry was not made.

Both of these companies mine and mill asbestos in quantities comparable to the Coalinga Company. That is, about 90.7 metric tons (100 short tons) of asbestos are produced per day. Mining techniques appeared to be essentially the same. The major difference was that the Union Carbide Mine was very orderly, with regular tiers and layers. The Atlas Mill appeared to be very similar to the Coalinga Mill.

Visible emissions were apparent from the drier exhaust stack where a cyclone control device is used.

THE PACIFIC ASBESTOS COMPANY, COPPEROPOLIS, CALIFORNIA

Date: September 19, 1973

General

It was desirable to visit this mine for two reasons. Firstly, it is unique among the California asbestos mines in that it has the more usual form of long fibered chrysotile. Secondly, it is in reasonable proximity to Coalinga and was the only remaining large mine for which we had no information. Because of the relatively short distance to the Copperopolis location, it was decided to gain as much information as possible from the exterior.

Location Visit

The mine and mill are located some 80 km (50 miles) east of Stockton, California. It is reached by taking Highway 4 for 64 km (40 miles) east from Stockton to Copperopolis. At Copperopolis, turn right, pass through the very small village, and follow the road southeast for about 6.5 km (4 miles). The mine entrance is on the left, a private road climbs into the hills for about 4.8 km (3 miles) to the mine and mill.

Viewed from the road, it is obvious that the mining and milling operations are very similar to other locations. The ore tailings piles and roadways are extensive and did not appear to have emission control. Similarly, the transportation by conveyors and trucks, and the dumping of asbestos did not appear to be controlled. At the time of the visit, no visible emissions were seen from the mill, although the mill could have been shut down at the time.

Discussions with the Coalinga asbestos mill operators suggest that the operation is standard in terms of emission control. A baghouse has been placed on the air aspiration system and a cyclone on the ore drier.

UNION CARBIDE MILL, KING CITY, CALIFORNIA

Date: November 14, 1973

General

The mill is located off of Highway 101 near King City, California. To visit the mill, the nearest airport is San Francisco. King City is 280 km (175 miles) south of San Francisco on Highway 107. The mill is 8 km (5 miles) south of King City on Highway 107 at the Wildhorse Road cut-off. Pass under Highway 101 and turn right at the next junction onto Cattleman Road. Follow the road for about 1.6 km (1 mile). The mill entrance is on the left hand side.

The nearest motel is the Sage Motel at 633 Broadway, King City, California 93930. Telephone 408/385-3274.

The manager at the mill is Mr. Floyd Laresson. The telephone number is 408/385-5961. The mill employs 66 to 70 persons. The mill operates three shifts a day, seven days a week. About 8 to 10 mill operators are required per shift.

Milling Operations

Ore is brought the 112 km (70 miles) from the Coalinga area by truck. It contains 15 to 20% water and 5 to 10% magnetite. Associated with the asbestos are varying amounts of silica and serpentine rock. About 145 metric tons (160 short tons) of ore are processed per day to yield 90.7 metric tons (100 short tons) of asbestos. An extensive ore stock pile is maintained at the mill.

Water is plentiful at the King City location. It is obtained from a well. Approximately 90.7 metric tons

(100 short tons) of water are used per day in the unique asbestos wet milling process.

The ore arriving at the mill was graded at the mine by passing it through a 12.5 mm (5 in.) grizzle. At the start of the milling process, the asbestos is slurried by spraying with water as it passes over a 6 mm (¼ in.) screen. The fine fraction is then passed through a cyclone separator and through a series of fiber opening and separation stages as shown in Figure 10. Magnetic separation is used to remove iron oxides.

The separated asbestos slurry is filtered through a large filter press system containing six banks each about 9.1 m (10 yd) long. To remove the water, shriver filter presses with 1.2 x 1.2 m (48 x 48 in.) plates operate at 5.5×10^5 N/m^2 (80 psi) pressure. The filtration step is expensive -- to replace the polypropylene filter costs \$36,000 to \$38,000 per year.

Filtered asbestos is then extruded through 12.5 mm (½ in.) orifices and passes into the drier. A knife blade cuts off the pellets at about 2.5 cm (1 in.) in length. A rotary drier with concurrent air flow is used to dry the pellets. Exhaust gas is 132° C (270° F) versus 650° C (1,200° F) on entry. Pellets are then broken in mills to release the fibers. Asbestos is pressure packed in paper bags. Bagging machines are enclosed and the bagging room is isolated. Bags are placed on pallets for shipping.

Three grades of asbestos are produced, no attempt is made to compare them to Canadian type grades. Some is shipped in pellet form. For use in paper, titania is added. For use in mining, aluminum silicate is added. High purity material is obtained by giving a double magnetic separation. The short fibered asbestos has many uses. Chief among these

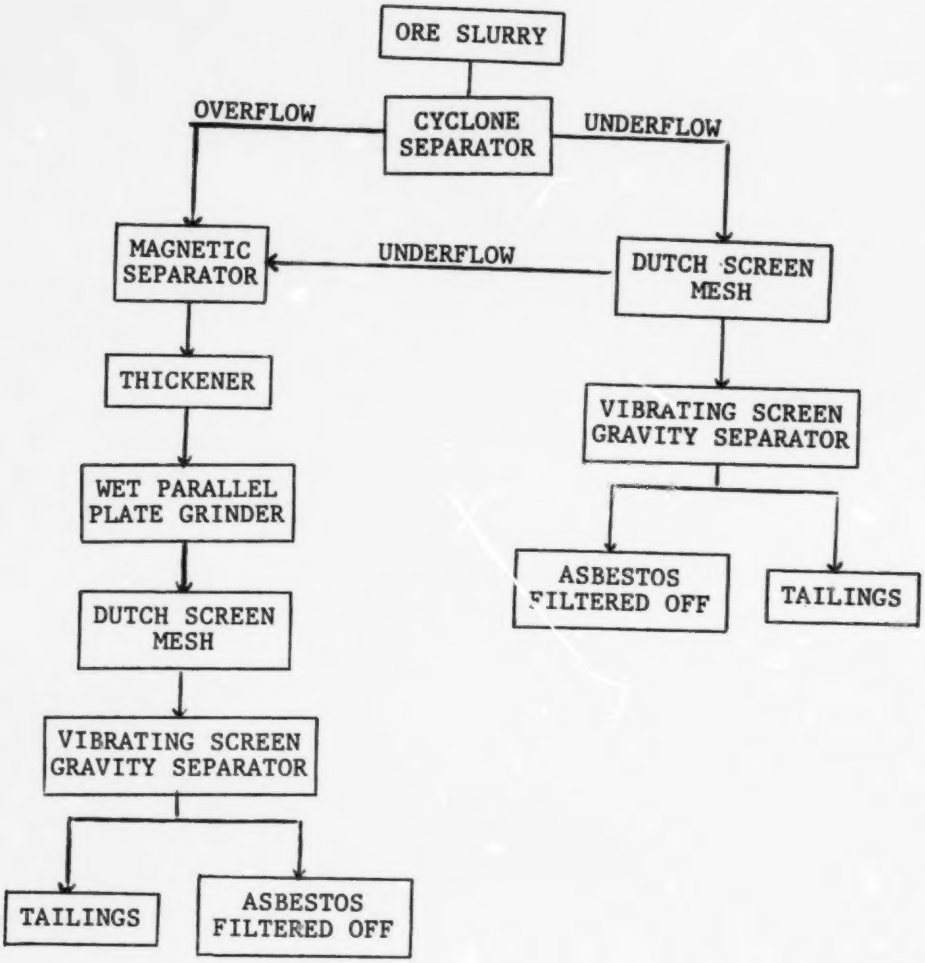

ORE SLURRY
OVERFLOW
CYCLONE SEPARATOR
UNDERFLOW
MAGNETIC SEPARATOR
UNDERFLOW
DUTCH SCREEN MESH
THICKENER
VIBRATING SCREEN GRAVITY SEPARATOR
WET PARALLEL PLATE GRINDER
ASBESTOS FILTERED OFF
TAILINGS
DUTCH SCREEN MESH
VIBRATING SCREEN GRAVITY SEPARATOR
TAILINGS
ASBESTOS FILTERED OFF

Figure 10. Flow sheet for asbestos wet-milling process

is its use as a filler/strengthener in floor tile. It is also used in paper, ceiling tile, as a filler in thixotropic resins, and as a lubricant in oil well drilling. Japan is the mill's largest customer.

Emission Control

It is immediately apparent, from observing the mine with its neat terracing and shelving and from the orderly mill appearance, that the Union Carbide operation is a well organized business.

Emissions from the ore pile are kept to a minimum by spraying with water. This activity is not costly since water is plentiful and the ore will be slurried eventually anyway. This is in contrast to the dry air aspiration processes where the addition of water adds a costly burden to the conventional first step, that is, ore drying.

Conditions inside the mill are strikingly cleaner than other asbestos mills or processing plants. No dust to be seen anywhere except in the bagging room. The bagging of asbestos is undertaken in enclosed, air-swept booths in an isolated room. The external surfaces of the bags are air-swept to remove most of the loosely adhering fibers. Air from the bagging enclosure is exhausted through a baghouse system.

Air from the ore dryer and from the bagging plant is exhausted through baghouses. Two baghouses of 2.83×10^5 lpm (10,000 cfm) and 5.4×10^5 lpm (19,000 cfm) capacity are used. Since the air from the driers is hot (about 125° C, 257° F), and contains moisture, insulated baghouses are used to avoid condensation as the gases cool. The bags are made from Nomex to withstand the high temperatures. The units are of the pulse-air cleaning type and were made by Industrial Filtration, Inc.

Another feature which is unusual, if not unique, among asbestos companies of the United States, is Union Carbide's current program of building changing rooms with lockers and showers. Workers leaving asbestos plants with asbestos adhering to their clothing constitute an individual, unenclosed, asbestos emission source which could constitute a threat to the person's immediate family. It is hoped that the company will require workers to have a complete change of clothing before leaving the plant.

Tailings from the plant are carried in a very wet state to a tailings dump. As the tailings dry, they will become subject to erosion and constitute an emission source. There is no program at present to stabilize this emission source.

Waste water from the plant is considerable in quantity. At the time of the survey, the company was negotiating with local pollution authorities for permission to continue to dump this waste water into the sewer system.

The use of paper bags as containers for the asbestos product creates two problems which are of concern to the Union Carbide management. One is that they split and allow fibers to spill out. The other is that asbestos fibers cling and cake onto the paper and are subsequently causing emissions. Plastic bags would be superior because they are tougher and the smooth surface would be more easily blown clean. Paper bags persist because customers specify their use to reduce costs.

THE GAF ASBESTOS MINE AND MILL, EDEN MILLS, VERMONT

Date: October 10, 1973

General

The GAF Corporation asbestos mine and mill is located in Vermont. The nearest airport is Burlington. From Morrisville follow Route 100 north for about 24 km (15 miles) to

Eden Mills. From the center of this very small community, a secondary road winds northwest; the plant is located on the left side about one mile up this road. The nearest motel is the Sunset Motel in Morrisville, telephone 802/888-4956.

The manager of the plant is Mr. Ronald K. White; the telephone number is 802/635-2311. The plant has a staff of about 200. About 60 workers are engaged in the mining operations and about 140 in milling. The mill is operated three shifts a day, six days per week. Approximately 136 metric tons (150 short tons) of ore are handled per hour.

Mining Operations

The ore is mined on the Belvidere Mountains in Orleans County, Vermont. The deposit is an outcrop of the extensive deposits which are mined in Canada some 160 km (100 miles) across the border. The area is sparsely populated.

The ore is removed from a terraced open-pit mine on the mountain side. A series of blast holes are drilled along the edge of a terrace using Ingersoll Rand or Reich drills. The drills are fitted with cyclone dust collectors; some emissions are created. Primary blasting is carried out every 8 to 10 days to free large sections of rock. Secondary blasting to break-up large boulders is undertaken every day. The rock has a moisture content of between 1 and 15%. Water could be seen seeping through the mine face and forming large puddles on the pit-floor.

The rock is lifted by mechanical shovel into 31.8 metric ton (35 short tons) trucks and is carried to a storage pile near the rock crushing unit. The roadways in the mine area are covered with 12.5 mm to 25 mm (½ in. to 1 in.) rock chips obtained from the ore crusher.

Emission Control at the Mine

Little or no attempt is made to reduce the emissions from the mining operations. The drills are equipped with cyclones but they are of limited effectiveness. Blasting, shovelling, hauling, and dumping are all uncontrolled. The roadways are made from rock chips and are dusty when traversed. Some oil spraying has been undertaken and was reported to reduce the dust emissions. The ore is dumped into a covered jaw crusher, but it is not enclosed nor is it vented through a control device.

Milling Operations

Milling is undertaken in a four story building built in 1948. The asbestos is extracted by the normal asbestos industry method of repetitive crushing and air aspirating off the released fibers.

Ore from the mine is crushed by a large 149 KW (200 HP) jaw crusher; this breaks the rock into 16.2 cm (6 in.) pieces. It is then reduced to 2.5 cm (1 in.) pieces using an eccentric crusher. The crushed wet rock is stored prior to the drying stage; 68,058 metric tons (75,000 short tons) of wet ore are stored at this point. The crushed ore is then passed through a rotating drier. Hot air enters the drier at 900° C ($1,700^{\circ}$ F) and exits at 70° C (150° F). Dried ore is then stored in hoppers ready for the fiber extraction process.

The extraction process follows a complex route through the mill floors starting from the top. It is a dusty process. The ore is carried by gravity and a series of open conveyors. Extracted fiber is carried by an air stream to the various collection points. Seven asbestos grades, from long spinning quality to short filler material, are collected. Fiber is pressure packed into paper or plastic bags. The bags are then palletized before shipment.

Waste rock material tailings and waste material from the baghouses are carried by a long conveyor belt system to the tailings pile. The tailings piles are extremely large and cover some 0.2 km^2 (50 acres) of ground. The height of the pile is difficult to estimate because of the uneven terrain; however, it is about 152 m (500 ft) at its highest point.

The conveyor system is actually a series of ten separate conveyors; each is enclosed. At the meeting point of the conveyors, there is a motor house which is vented without control, creating visible emissions. Emissions are created as the tailings tumble from one conveyor to the next. Since men enter the conveyor houses for maintenance and the control of the system, the houses are ventilated. The vented air is an obvious and visible source of emissions from each house.

The tailings are discharged onto the top of the tailings pile. A bulldozer is used to distribute the tailings on the top surface. The bulldozer is also used to relocate the end of the conveyor discharge. Each of these operations creates emissions.

Emission Control at the Mill

The GAF mill is currently operating under a EPA, NESHAP's waiver, which extends until March 15, 1975. The company has stated that the required controls are too expensive and that they will be forced to close their plant. In order to comply with EPA requirements, they will be obliged to fit baghouse emission control units at the following emission points[71].

A. Primary crushing building ventilation air stream that has a flow rate of 1.42×10^5 lpm (5,000 cfm).

B. Secondary crushing building ventilation air stream that has a flow rate of 1.42×10^5 lpm (5,000 cfm).

C. Two conveyor transfer points, each with ventilation volumes of approximately 8.5 x 10^4 lpm (3,000 cfm).

D. Two asbestos ore dryers, each with a flow rate of 7.1 x 10^5 lpm (24,000 cfm).

E. Tertiary crushing with a flow rate of 7.1 x 10^5 lpm (25,000 cfm).

F. Dry dock storage ventilation gas stream, with an approximate flow rate of 5.66 x 10^5 lpm (20,000 cfm).

G. Twelve tailings conveyor transfer points ventilation air streams, each with a flow of approximately 8.5 x 10^4 lpm (3,000 cfm).

Other emission sources which are not controlled by the NESHAP standard are: 1) the discharge of wet rock and the tailings from the conveyor onto the piles, 2) mechanical movement of wet rock and tailings for distribution on the piles, 3) vehicle traffic on the mill site, and 4) wind blown emissions from storage and tailings piles.

The air used for [illegible] of the fibers and for ventilating the mill is [illegible] passed through two baghouse filters of 8.5 x 10^6 lpm (300,000 cfm) and 2.1 x 10^6 lpm (75,000 cfm) capacity. The larger unit is the more conventional type with the fan on the exhaust side. The smaller unit is a pressure type and the fan is on the inlet side. During the winter months, air is recirculated within the plant to conserve heat. Since the inside of the plant is noticeably dusty, this would mean that air emerging from the plant via windows and doors would in all probability be less clean than that from a baghouse stack emitting directly to the ambient air.

The air from the ore dryer is currently passed through two clusters of four high-efficiency cyclones. GAF are of the opinion that baghouses cannot function with hot, wet gases when the ambient temperatures are very low as during the winter months in Vermont. This is because of dew-point condensation causing plugging. However, this problem has been eliminated by heavy insulation at the Johns-Manville plant in Asbestos, Canada.

It was noted that, despite the age and established nature of the tailings dump, there is no vegetation cover. The huge piles are a dull grey color.

THE CERTAIN-TEED AND NICOLET WASTE DUMPS, AMBLER, PENNSYLVANIA

Date: August 30, 1973

Survey reported by A. Lee and S.L. Roy of the Environmental Standards Enforcement Division (ESED) of the EPA.

General

The Certain-Teed and Nicolet companies process asbestos materials at two sites located approximately 24 km (15 miles) northwest of Philadelphia, Pennsylvania. The Certain-Teed plant is located approximately 400 m (1,200 ft) southeast of the Nicolet plant. The nearest motel is the Sheraton Motor Inn at the Fort Washington Interchange on the Pennsylvania Turnpike. Nicolet produces monolithic board and gasket material while Certain-Teed produces asbestos cement pipe. Their waste dumps are located next to each other.

Plant Descriptions

The draft of the ESED survey reports that the Nicolet Industries' operation in Ambler, Pennsylvania currently is at two locations. Plant No. 1 is the main plant and produces high-density and low-density monolithic board and gasket material that contain commercial asbestos. Several other asbestos-containing products are produced on a smaller scale at the plant. The monolithic board is sent to Nicolet Plant No. 2, located several blocks away, for grinding, sanding, polishing, and sizing. The dust that is generated during the finishing operation at Plant No. 2 is collected in hoppers and is transported once a day (at approximately 6:15 a.m.) to Plant No 1's waste-water settling pond. The material in the hopper is reportedly wetted down and covered to eliminate wind blown emissions during transport. The transfer and dumping operation was not observed by the ESED, because it had occurred prior to the visit. The grayish-black, asbestos-containing dust is dumped into one of three settling ponds and mixed with water emanating from the large board and gasket presses at Plant No. 1. The settled sludge from the three primary settling ponds is pumped to a large lagoon, the overflow from the settling ponds is pumped to a large lagoon, the overflow from the settling ponds passes through a series of settling ponds and porous filtering beds prior to being discharged into a stream.

Empty bags that contained commercial asbestos and other solid waste materials generated at both Nicolet plants were reportedly collected and removed from the plant sites by a private contractor. The ultimate disposal of these wastes is not known.

The report further states that the Certain-Teed plant produces asbestos cement pipe as its major product. Liquid and solid wastes from the manufacturing operation are slurried and transported to a settling and dewatering lagoon by tank trucks.

Inactive Disposal Sites

A waste disposal site, described in the ESED draft, was located southwest of the Nicolet Plant No. 1. This site has been inactive for about four years. The type of waste material deposited at this site is described as very different than the material currently being disposed of at the active Nicolet site.

Large pieces of solid waste materials were observed by the site team on this inactive site, which covers approximately 40,000 m^2 (10 acres). Trees, grass, shrubs, and weeds reportedly covered approximately 75 to 90% of the surface area of this inactive pile. No vegetation was observed to be growing on the north bank of the pile. This bank was described as being approximately 183 m (200 yd) long and approximately 15 m (50 ft) high, with a slope of about 60 degrees. The white barren bank of the waste pile was said to completely border one side of a playground and was very close, within 15 m (50 ft), to an occupied dwelling. At the time the inactive waste disposal site was visited by the ESED, no children were playing on the pile; however, children were playing in the playground near the pile. A member of the site team, in a discussion with a local resident, reported that visible dust emissions do not generally occur from the pile. The surface of the barren bank of the disposal pile was described as granular in nature; however, the granules could be broken into a dusty material if strong pressure were applied.

Another older inactive asbestos waste disposal site, located close to Nicolet Plant No. 2, was observed by the site team to be completely covered with trees, grass, and weeds. This particular site was generated by an asbestos-using industry which is no longer in operation. The ESED report states that it is unlikely that major asbestos emissions would occur from this inactive site.

Active Disposal Sites

The presently active disposal sites of the Nicolet and Certain-Teed plants were reported to be adjoining one another. The Nicolet site is described as approximately 18 m (60 ft) high and the Certain-Teed site is approximately 6.1 m (20 ft) high. The Nicolet site is reported to be the older site and currently growing at a slower rate than the Certain-Teed site. The slurried waste settling and dewatering lagoons for the Nicolet and Certain-Teed plants were reported to be separated by approximately 91 m (100 ft).

The Nicolet waste disposal area, where the slurry is pumped, is described as approximately 91 m (300 ft) wide by 152 m (500 ft) long. The waste pile is stated to be approximately 18 m (60 ft) higher in elevation than the main plant level and approximately 64 m (210 ft) away from the main plant. The top layer of the dewatering lagoon is described as dry and crusted over with many cracks in this surface layer. This top layer is reported to be light in color, having a low density, and fibrous. The ESED report states that these fibers appeared to be bound securely enough so that they would not be released by the wind. The sides of the disposal site are described as about 46 cm (1.5 ft) higher than the level of the lagoon and form a roadway approximately 4.6 m (15 ft) wide. Solid material is deposited and spread on this roadway when it becomes necessary to build up the sides of the pond. Reportedly, the material used to build the roadway does not contain asbestos. Rocks removed from the rock bed filters and other solid material are used for this purpose. The report cites the possibility for some wind blown emissions to occur from the roadway and the banks of this waste disposal site.

The Certain-Teed waste disposal site is reported to be similar to the Nicolet site; however, the waste slurry is transported to the lagoon in tank trucks instead of being pumped. Each truck carries approximately 26,400 liters (6,000 gal) per load and empties into the lagoon at a rate of about 10-12 truckloads per six-week period. When the lagoon is filled (approximately every six weeks), the dewatered sludge is dredged out of the lagoon and dumped on the solid waste area where it is subsequently mixed by a bulldozer with crushed, discarded, asbestos-concrete pipe to stabilize the disposal pile. The lagoon dredging operation was observed during the ESED visit and did not generate visible emissions. The bulldozer could possibly generate visible emissions when crushing the pipe and mixing it with dewatered sludge, but this operation was not observed by the site team. The solid waste area was described as being well compacted; however, some dust was created by a dump truck moving dredged sludge. The report states that is is possible for wind blown emissions to occur from this area. The material on the surface reportedly appeared to fibrous in nature, but the fibers appeared to be securely bound to larger material.

SECTION 6

FIELD TESTING FOR ASBESTOS EMISSIONS

GENERAL SAMPLING SCHEME

Field sampling was undertaken to obtain preliminary information on the extent of the emissions from asbestos mines and waste dumps. Although actual conditions at a given sampling site necessitated changes, the following general plan was formulated.

A system of six Hi-Vol ambient air samplers was employed to sample the emission source. The samplers were positioned in pairs along the line of the wind during the sampling period. A mechanical weather station was placed on the emission source near the most active region. The weather station recorded the wind speed, wind direction, and air temperature. One pair of Hi-Vol samplers was situated approximately 400 m (¼ mile) upwind of the weather station. The other two pairs of Hi-Vol samplers were positioned downwind at approximately 400 m (¼ mile) and 2 km (1¼ mile). The use of two Hi-Vol samplers at each sampling location enabled simultaneous sampling to be carried out at elevations of 2 m (6 ft) and 7 m (20 ft). The sampling elevation of 2 m (6 ft) was chosen because it is near the human breathing zone and yet high enough to minimize filter contamination from surface soil and plant parts. The latter could be caused by disruption of the soil and vegetation by the Hi-Vol sampler's exhaust. The elevated sampler was at a height of 7 m (20 ft). Physical limitations in erecting the Hi-Vol sampler dictated this elevation. A sampling height of 10 m (30 ft), the standard height for measuring surface winds according to the World Meteorological Organization and the National Oceanic and Atmospheric Administration, was the preferred elevation. For consistency, the weather station was erected to the same 7 m (20 ft) elevation. A schematic diagram of the sampling site is shown in Figure 11.

The ambient air samples were collected on Millipore filters of 0.8 μm pore size. The sampling times ranged from ½ to 4 hours in length, depending on the site conditions. The Hi-Vol samplers used were manufactured by B.G.I., Inc. The samplers used at the 7 m (20 ft) were the universal model equipped with Bendix 20.3 cm x 25.4 cm (8 in. x 10 in.) filter heads. The 2 m (6 ft) samplers were the Type I model without the rain hood. The samplers have rotometers attached to indicate flow rate. The rotometers were calibrated in the laboratory using the Bendix Hi-Vol calibrator and a Dwyer manometer. The total volumetric flow was the average of the initial and final flow rates times the sampling time. In the present study the very low dust loading resulted in virtually no change in pressure drop across the filter; thus, the initial and final flow rates were identical.

The mechanical weather station was manufactured by Meteorological Research Instruments, Inc., model 1076. Three Sears 1,500 Watt, gas-powered alternators were used to supply electric power for the samplers.

FIELD SAMPLING -- COALINGA, CALIFORNIA

The site sampled at Coalinga, California, was an asbestos ore processing mill owned by the Coalinga Asbestos Corporation, a Division of the Johns-Manville Corporation. The mill and mine are located on private property 22.4 km (14 miles) northwest of Coalinga. The mill is situated in the hills at an elevation of 909 m (3,000 ft). The mine itself is higher

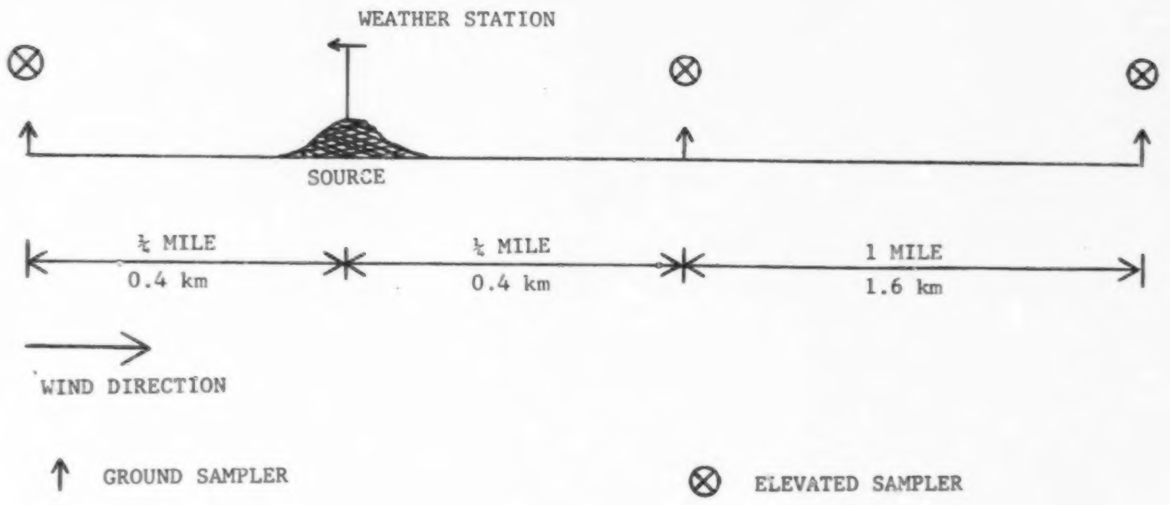

WEATHER STATION
SOURCE
¼ MILE
0.4 km
¼ MILE
0.4 km
1 MILE
1.6 km
WIND DIRECTION
GROUND SAMPLER
ELEVATED SAMPLER

Figure 11. Schematic diagram of sampling strategy

into the hills about 1.6 km (1 mile) away at an elevation of 1,212 m (4,000 ft).

Field sampling began on November 15, 1973, with the selection of sampling locations. Towers to accommodate the samplers at the 7 m (20 ft) elevation were erected. Figure 12 shows the relative sampling locations. The downwind location, No. 3, was not in direct line with the other locations and the wind direction because the hilly terrain made this impossible if the same altitude was to be maintained.

The onset of heavy rain and the temporary shut-down of the milling operations limited the number of samples that were taken. Ambient air samples were taken between rain showers only at the 2 m (6 ft) elevation. Two samples were taken at each of the three sampling locations. Sampling times were 30 minutes and one hour. Conditions at the mill site were very wet. Only those tailings which were actually being dumped were in a dry, dusty state. Effectively, all other emission sources could be considered controlled. The wind during the sampling period was blowing from the south down the valley at a velocity of 6.26 m/sec (14 mph). The ambient air temperature was 6.1° C (41° F).

FIELD SAMPLING -- WAUKEGAN, ILLINOIS

The Johns-Manville Asbestos-Products Manufacturing plant at Waukegan, Illinois, is located on 0.35 km^2 (87 acres) of Lake Michigan shoreline. The waste dump itself covers only about 8,000 m^2 (2 acres). It is rectangular in shape, approximately 150 m by 450 m (165 yd by 495 yd). The dump rises to a height of 9.14 m (30 ft) above the general level of the plant site. The northeast corner of the dump is the most active face.

The dump contains waste in which the asbestos is both tightly and loosely bound. Waste from asbestos-cement,

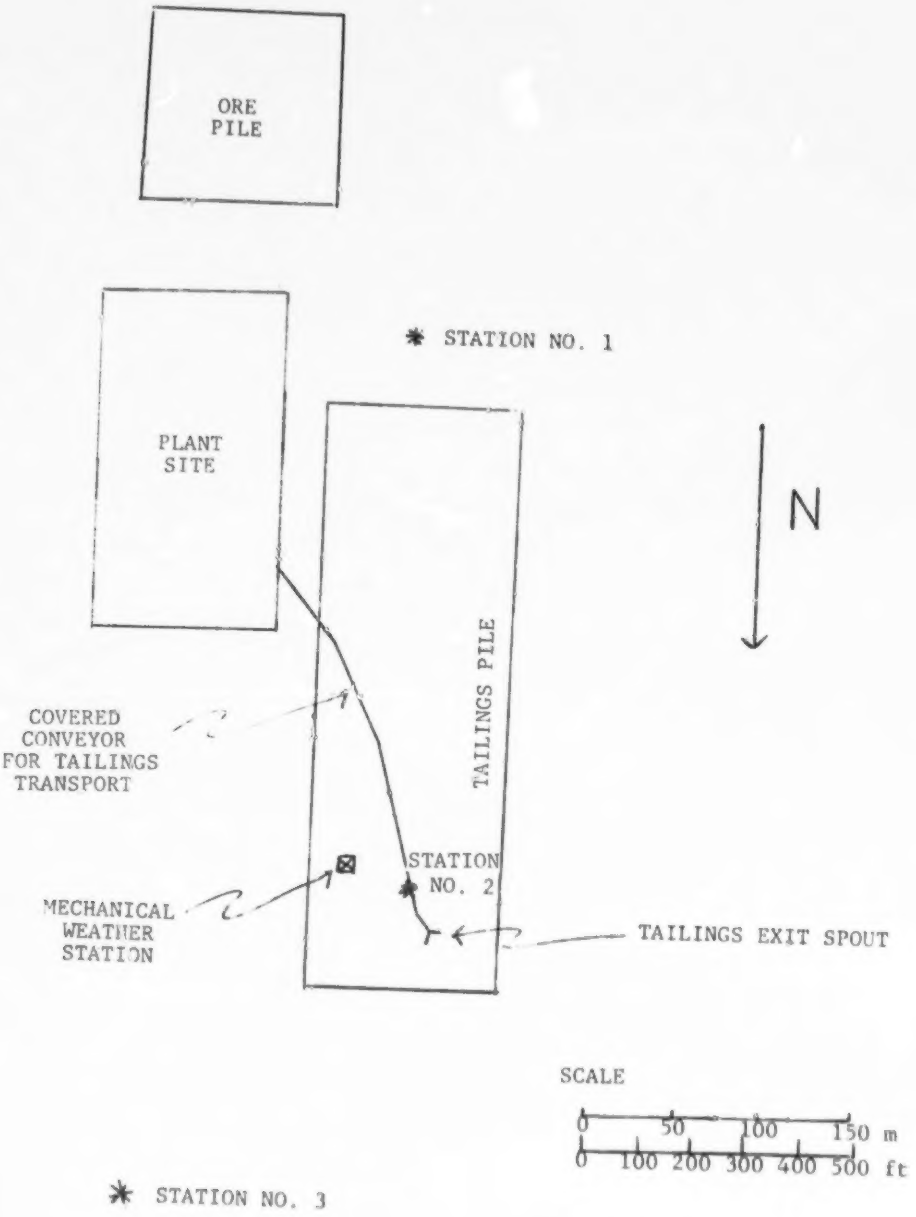

ORE PILE
PLANT SITE
STATION NO. 1
N
TAILINGS PILE
COVERED CONVEYOR FOR TAILINGS TRANSPORT
STATION NO. 2
MECHANICAL WEATHER STATION
TAILINGS EXIT SPOUT
SCALE
0 50 100 150 m
0 100 200 300 400 500 ft
STATION NO. 3

Figure 12. Schematic layout and sampler locations, Coalinga, California

friction materials and floor tile operations has asbestos fiber held in a strong matrix. The material itself is not easily broken apart. Waste from asbestos-paper and building-board manufacturing operations is more friable and the asbestos fiber is less securely bound to the product. The asbestos waste from the settling ponds and from the baghouse collectors is loose and has the greatest potential for becoming airborne.

The operation at the dump is continuous from 7:30 a.m. to 3:30 p.m.; occasionally a dump truck adds waste during the evening shifts. The waste is added to the active face from the top of the dump. Asbestos-cement pipe is broken and the waste is compressed by a 54.4 metric ton (60 short ton) bulldozer. The top surface of the dump is covered with top soil and vegetative stabilization is being attempted on the inactive south face of the dump.

Field sampling was started on December 3, 1973. Snow, rain, and freezing temperatures delayed sampling; however, the preliminary work was completed. Samplers were erected at elevations of 2 m (6 ft) and 7 m (20 ft). Because the wind was blowing across the dump onto Lake Michigan, only one downwind sampling location was possible. Samples were also taken next to the weather station on top of the dump (sampling location No. 2). Figure 13 shows the relative position of the sampling stations.

The ambient air samples were collected on December 8, 1973, with a minimum sampling period of three hours. At the time of sampling, the surface of the pile was frozen. This meant that emissions from the dump were effectively controlled. The wind on December 8th was blowing from the south to southwest (180° to 225°) with velocities varying from 4.47 to 6.70 m/sec (10 to 15 mph). The ambient air temperature was 0° C (32° F) at noon, decreasing to -1.1° C (30° F) by 4:00 p.m.

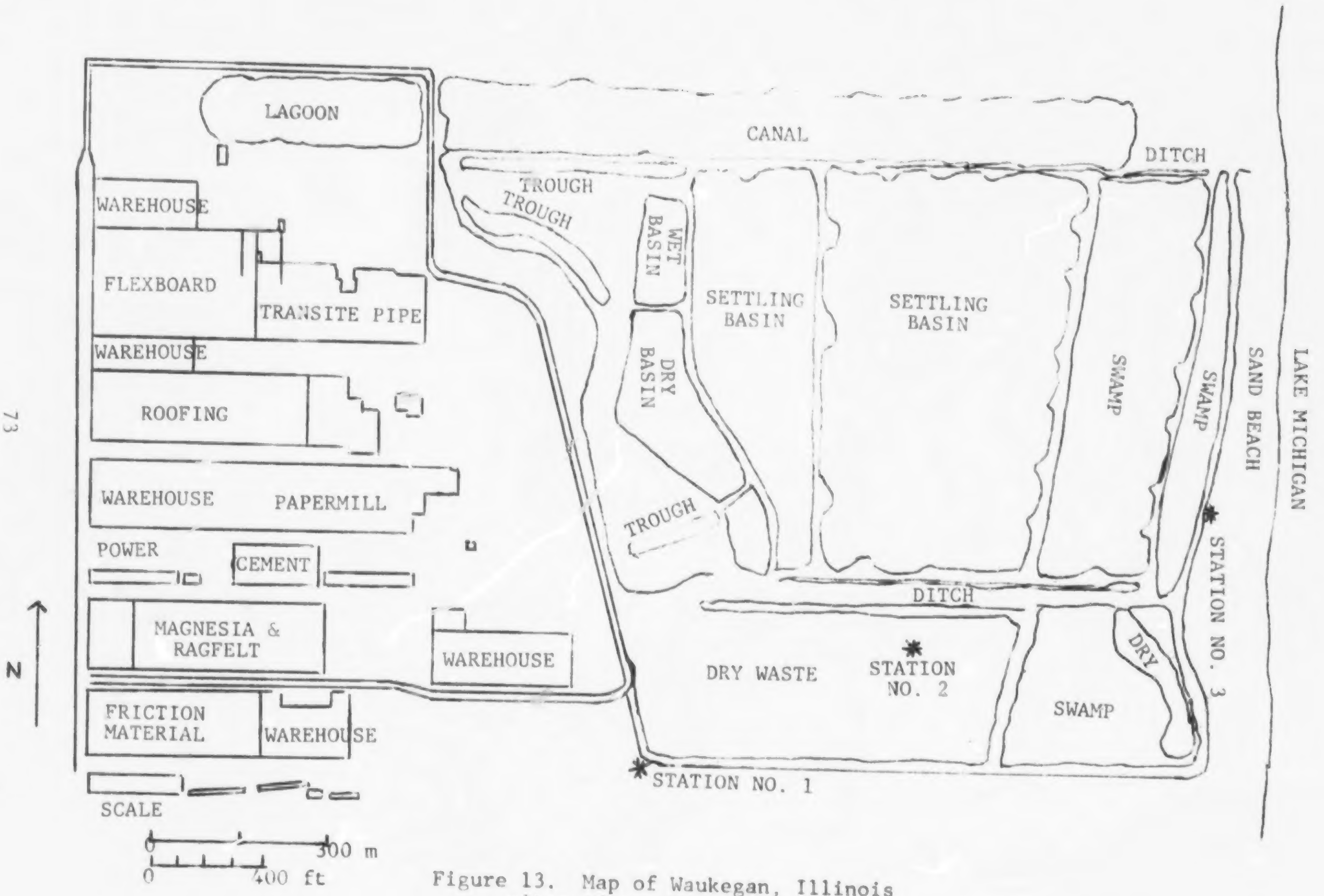

LAGOON
CANAL
DITCH
TROUGH
TROUGH
WET BASIN
SETTLING BASIN
SETTLING BASIN
SWAMP
SWAMP
SAND BEACH
LAKE MICHIGAN
WAREHOUSE
FLEXBOARD
TRANSITE PIPE
WAREHOUSE
DRY BASIN
ROOFING
WAREHOUSE
PAPERMILL
TROUGH
POWER
CEMENT
DITCH
STATION NO. 3
MAGNESIA & RAGFELT
WAREHOUSE
DRY WASTE
STATION NO. 2
DRY
SWAMP
N
FRICTION MATERIAL
WAREHOUSE
STATION NO. 1
SCALE
0
300 m
0
400 ft

Figure 13. Map of Waukegan, Illinois site and sampler locations

FIELD SAMPLING -- DENISON, TEXAS

The Johns-Manville Asbestos-Cement Processing plant at Denison, Texas, is located on level terrain near the Red River. Waste material consisting of crushed fragments of asbestos-cement pipe in which the asbestos is locked in a durable cement structure and waste materials collected in the baghouse hoppers are deposited on this dump. In addition, sludge from the asbestos-cement processing water settling pond is placed onto the dump. Waste material is sporadically and inefficiently water sprayed to reduce emissions. When a sufficiently large area is buried and distributed, it is earth covered. The dump is irregular in shape, but can best be approximated by a square covering 0.044 km^2 (11 acres). The different sampling times were used to insure at least one set of samples with a fiber density suitable for inspection by both optical and electron microscopy.

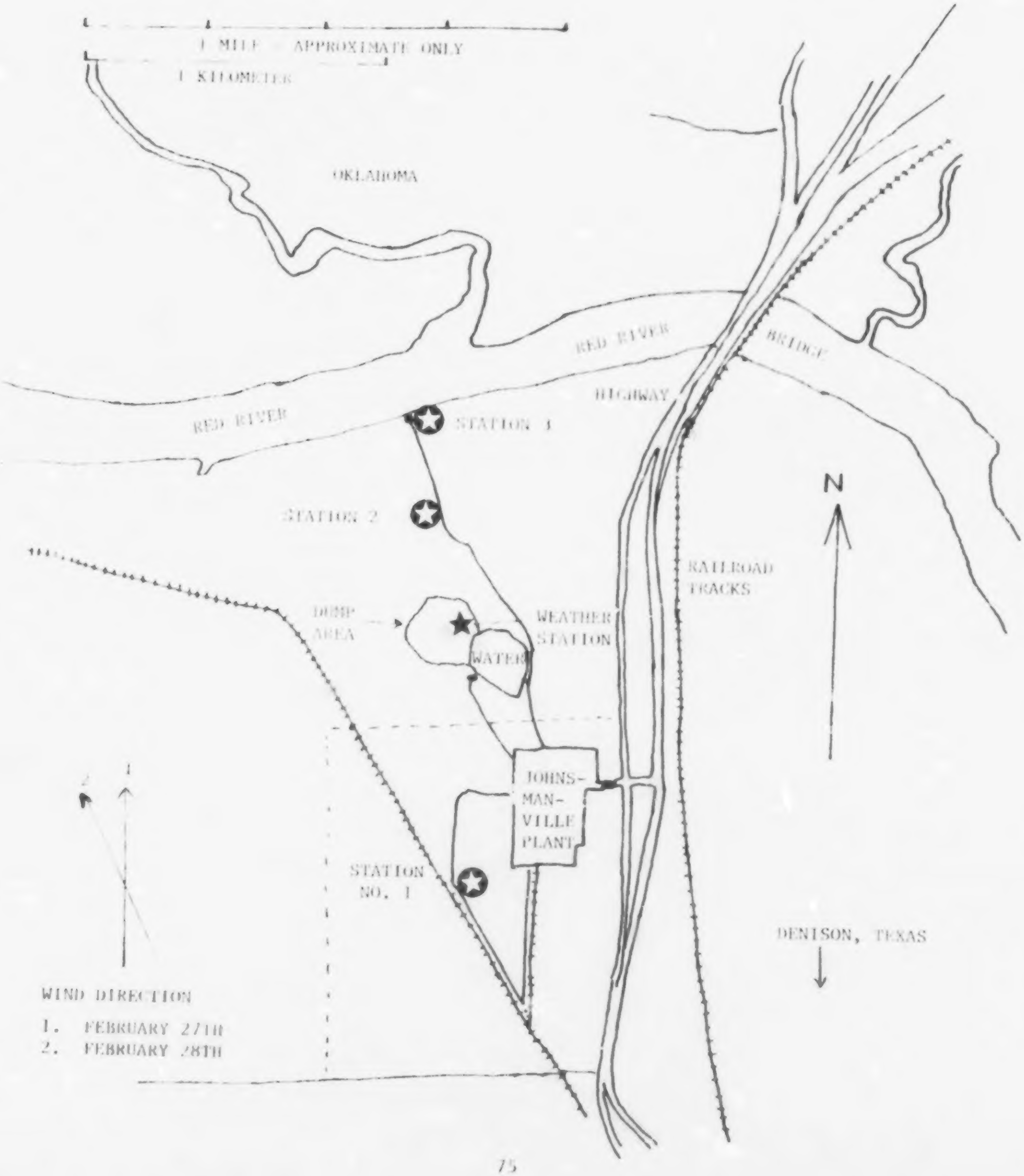
On February 27th, the wind was gusty, averaging 8.94 m/sec (20 mph), blowing from the south (165° to 195°). The ambient air showed a warming trend; being 12.2° C (54° F) at the start of the sampling period, and rising to 16.7° C (62° F) four hours later. On the second sampling day, February 28th, the wind was steady at 4.92 m/sec (11 mph) and from the south to south-southeast (150° to 180°). The ambient air temperature was stable at 17.2° C (63° F).

ANALYSIS OF SAMPLES

Optical Microscope Instrumentation

A Zeiss Universal Research microscope and a Leitz Ortholux microscope were used for optical counting and sizing airborne fibers. They were both fitted with phase-contrast optics. The size of the field of view was measured using a stage micrometer. The objective lens on both microscopes were 4 mm. The field of view on the Zeiss was 9.62×10^{-4} cm^2

Figure 14. Map of Johns-Manville site, Denison, Texas


1 MILE - APPROXIMATE ONLY
1 KILOMETER
OKLAHOMA
RED RIVER
BRIDGE
HIGHWAY
RED RIVER
STATION 3
STATION 2
N
RAILROAD TRACKS
DUMP AREA
WEATHER STATION
WATER
JOHNS-MAN-VILLE PLANT
2
1
STATION NO. 1
DENISON, TEXAS
WIND DIRECTION
1. FEBRUARY 27TH
2. FEBRUARY 28TH

at a total magnification of 650X. The Leitz had a field of view of 6.51×10^{-4} cm^2 at a total magnification of 500X. All particles having a 3:1 aspect ratio were counted. The minimum particle diameter counted was 0.5 μm.

Sample Preparation for Optical Counting

Samples were prepared for optical counting in the following manner. All operations were carried out in a Farr clean bench. A triangular section, about one square centimeter in area, was removed from the central region of the filter using a scalpel and tweezers. This section was then placed, particle side up, onto one or two drops of mounting fluid on a glass slide. The mounting medium was a 1:1 solution of dimethyl phthalate and diethyl oxalate. The refractive index of this medium is 1.47. The filter was allowed to clear for 15 to 30 minutes. A clean cover slip was then placed over the filter. The prepared samples were counted within 24 hours of preparation (usually less than 6 hours).

Electron Microscope Analysis

The electron microscope used was a Hitachi HU-11 transmission electron microscope. This instrument was calibrated using standard grids. The magnification to the photographic plate was 18,000X. However, the counting was done on an optical viewing screen. A factor of 1.1 relates the photographic plate and the optical viewing screen. Therefore, the effective magnification was 16,364X. The measured field of view was 1.34×10^{-7} cm^2. Fibers as small as 0.020 μm in diameter could be measured at this magnification.

It was originally planned to use a scanning electron microscope and interrogate the image using a Quantimet 720 image analyzer. However, it became obvious after a preliminary series of experiments that this was not a practical method. The JEOL 50A SEM with a theoretical resolution limit of 100 Å could not resolve the finest asbestos fibers of 200 Å diameter. In addition, the present electronics on the IITRI Quantimet 720 are not capable of distinguishing the small fibers from the background because of the low contrast levels between the fibers and the background. A further point was that the instrument could not evaluate the fibers when they were present as bundles; when two fibers touched or crossed; when a fiber was close to other particles; or when the fiber was very long and curved or looped.

Sample Preparation for Electron Microscope

To prepare a sample for electron microscope examination, a circle of 3.5 mm in diameter was cut from the center of the filter using a punch. This piece of filter was placed dust side up on a 100 mesh carbon-coated electron microscope grid. It was then placed in a "cold finger" condensation washer using acetone as a solvent. The acetone vapor washed away the filter media, depositing the collected particles onto the carbon substrate of the grid. The specimens remained in the condensation washer overnight to insure total dissolution of the filter media.

Criteria for Counting

In order to obtain an accurate estimate of the number of fibers, the statistical error resulting from the random distribution of fibers must be kept to an acceptably low level. The NIOSH criteria document on asbestos (HSM 72-10267) states that fiber counts follow a Poisson distribution. In this study, it was assumed that all fibers counted, whether by optical or electron microscope, followed Poisson statistics.

Based on a count of 100 fibers, the error at the 95% level of confidence would be two standard deviations. That is, $2 \times \sqrt{100}$, or ± 20. Therefore, a quoted value of 100 fibers should be accurate to within 80 to 120 fibers. The loading of particles on the filter determines the number of fields which need to be examined to count 100 fibers. In general, a minimum of 20 fields and a maximum of 100 fields were examined.

Calculation of Ambient Air Fibers Concentration

A field of view of the microscope is a small portion of the specimen. In order to relate the number of fibers counted to the ambient air fiber concentration, the following formula was used.

Ambient Air Fiber Concentration (number of fibers/m^3 of air)

$$= \left(\frac{\text{number of fibers counted}}{\text{number of fields counted}}\right) \times \left(\frac{\text{effective filter area } (cm^2)}{\text{area of microscope's field of view } (cm^2)}\right) \times \left(\frac{1}{\text{volume of air sampled } (m^3)}\right)$$

Results of the Analysis of Field Samples

The field samples were analyzed using both the electron microscope and the optical microscope. The samples were counted to determine the ambient air concentration of fibers and the size distribution by length of the fibers. No positive identification of the fibers as asbestos was made. Rather, it was presumed that the sampling locations provided apriori evidence that the fibers originated from the sites being sampled. The results of these analyses are summarized in; 1) Table 6 for the samples collected at Coalinga, California; 2) Table 7 for the samples collected at Waukegan, Illinois; and 3) Tables 8 and 9 for the samples collected at Denison, Texas.

Table 6. SAMPLING DATA AND AMBIENT AIR CONCENTRATIONS OF FIBERS IN THE VICINITY OF THE JOHNS-MANVILLE ASBESTOS MILL TAILINGS PILE, COALINGA, CALIFORNIA

November 19, 1973
Weather Data during Sampling Period: Wind, 6.26 m/sec (14 mph) from the South; Temperature, 6.1°C (41°F)

Sampling Data [1]				Fiber Concentration and Size Distribution by Optical Microscopy [2,4]					Fiber Concentration and Size Distribution by Electron Microscopy [3,4]					
Site Number	Sampling Elevation, m	Approximate Sampling Location with Respect to Active Face of Tailings Pile, m (ft)	Volume of Air Sampled, m^3	Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers				Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers				
					1.5-9.9 μm	10-19.9 μm	20-29.9 μm	>30 μm		0.048-0.06 μm	0.061-0.18 μm	0.181-0.36 μm	0.361-0.54 μm	0.541-1.49 μm
1	2	330 (1082) upwind	30.8	0.75×10^5	76	17	6	2	1.54×10^8	35	60	6	1	0
1	2	330 (1082) upwind	56.2	0.86×10^5	75	14	7	4	-	-	-	-	-	-
2	2	3 (10) at last conveyer transfer	26.7	7.39×10^5	74	16	7	3	1.58×10^8	19	40	26	15	0
2	2	3 (10) at last conveyer transfer	44.8	9.51×10^5	68	24	7	2	-	-	-	-	-	-
3	2	224 (736) downwind	13.6	9.31×10^5	77	17	4	2	5.93×10^8	38	41	12	6	4
3	2	224 (736) downwind	56.1	7.31×10^5	76	17	5	2	-	-	-	-	-	-

Samples were collected on 20.3 cm x 25.4 cm (8 in x 10 in) Millipore filters. The pore size was 0.8 μm and the effective filter area was 425.4 cm^2.

[1] Figure 12 is a location plot of the sampler locations at the sampling site.

[2] Phase contrast optics and a 4 mm objective lens were used for optical counting. The total magnification was 625X. The minimum fiber diameter included in the counts was estimated at 0.5 μm.

[3] Electron microscopy counting and sizing were done at a magnification of 16,364X. Fibers with a diameter as small as 0.016 μm were counted.

[4] Particles having an aspect ratio greater than 3:1 and approximately parallel sides were considered fibers.

Table 7. SAMPLING DATA AND AMBIENT AIR CONCENTRATIONS OF FIBERS IN THE VICINITY OF THE JOHNS-MANVILLE WASTE DUMP, WAUKEGAN, ILLINOIS

December 8, 1973
Weather Data during Sampling Period: Wind, 4.47-6.70 m/sec (10-15 mph) from the South to Southwest (180°-225°); Temperature, 0.0°C (32°F) at Noon, Falling to -1.1°C (30°F) at 4:00 P.M.

Sampling Data [1]				Fiber Concentration and Size Distribution by Optical Microscopy [2,4]					Fiber Concentration and Size Distribution by Electron Microscopy [3,4]					
Site Number	Sampling Elevation, m	Approximate Sampling Location with Respect to the Active Face of Waste Dump, m (ft)	Volume of Air Sampled, m^3	Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers [5]				Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers				
					1.5-9.9 μm	10-19.9 μm	20-29.9 μm	>30 μm		0.048-0.06 μm	0.061-0.18 μm	0.181-0.36 μm	0.361-0.54 μm	0.541-1.49 μm
1	2	336 (1200) upwind	116.7	0.38×10^2	100	0	0	0	5.58×10^7	44	46	8	1	1
1	7	336 (1200) upwind	97.3	3.15×10^2	71	14	14	0	4.48×10^7	31	55	10	2	2
2	2	Atop dump near active face	118.5	1.12×10^2	68	0	0	33	2.58×10^7	24	49	21	3	2
2	7	Atop dump near active face	155.7	1.99×10^2	57	29	14	0	1.48×10^8	37	51	7	3	2
3	2	336 (1200) downwind	104.8	2.11×10^2	100	0	0	0	6.07×10^7	16	50	26	5	3
3	7	336 (1200) downwind	107.0	2.48×10^2	68	17	17	0	2.69×10^7	22	42	30	3	3

Samples were collected on 20.3 cm x 25.4 cm (8 in x 10 in) Millipore filters. The pore size was 0.8 μm and the effective filter area was 425.4 cm^2.

[1] Figure 13 is a location plot of the sampler locations at the sampling site.

[2] Phase contrast optics and a 4 mm objective lens were used for optical counting. The total magnification was 625X. The minimum fiber diameter included in the counts was estimated at 0.5 μm.

[3] Electron microscopy counting and sizing were done at a magnification of 16,364X. Fibers with a diameter as small as 0.016 μm were counted.

[4] Particles having an aspect ratio greater than 3:1 and approximately parallel sides were considered fibers.

[5] Fiber concentration was <7 fibers in 100 fields counted.

Table 8. SAMPLING DATA AND AMBIENT AIR CONCENTRATIONS OF FIBERS IN THE VICINITY OF THE JOHNS-MANVILLE WASTE DUMP; DENISON, TEXAS

February 27, 1974
Weather Data during Sampling Period: Wind, Gusty Averaging 8.94 m/sec (20 mph) from the South (165°-195°); Temperature, 12.2°C (54°F) Warming to 16.7°C (62°F)

Sampling Data [1]				Fiber Concentration and Size Distribution by Optical Microscopy [2,4]					Fiber Concentration and Size Distribution by Electron Microscopy [3,4]					
Site Number	Sampling Elevation, m	Approximate Sampling Location with Respect to the Active Face of Waste Dump, m (ft)	Volume of Air Sampled, m^3	Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers				Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers				
					1.5-9.9 μm	10-19.9 μm	20-29.9 μm	>30 μm		0.048-0.06 μm	0.061-0.18 μm	0.181-0.36 μm	0.361-0.54 μm	0.541-1.49 μm
1	2	858 (2815) upwind	122.3	1.71×10^4	72	25	4	2	6.17×10^6	6	64	17	6	8
1	7	858 (2815) upwind	81.5	1.95×10^4	78	20	1	1	6.73×10^6	9	56	19	2	0
2	2	402 (1320) downwind	156.3	1.41×10^4	76	18	5	2	2.75×10^6	0	67	28	0	6
2	7	402 (1320) downwind	81.5	2.40×10^4	69	20	7	4	7.85×10^6	9	37	26	9	20
3	2	710 (2330) downwind	122.3	1.72×10^4	68	26	4	2	6.06×10^6	8	54	32	3	3
3	7	710 (2330) downwind	101.9	1.87×10^4	68	25	6	2	6.27×10^6	0	82	9	5	5

Samples were collected on 20.3 cm x 25.4 cm (8 in x 10 in) Millipore filters. The pore size was 0.8 μm and the effective filter area was 425.4 cm^2.

[1] Figure 14 is a location plot of the sampler locations at the sampling site.

[2] Phase contrast optics and a 4 mm objective lens were used for optical counting. The total magnification was 500X. The minimum fiber diameter included in the counts was estimated at 0.5 μm.

[3] Electron microscopy counting and sizing were done at a magnification of 16,364X. Fibers with a diameter as small as 0.016 μm were counted.

[4] Particles having an aspect ratio greater than 3:1 and approximately parallel sides were considered fibers.

Table 9. SAMPLING DATA AND AMBIENT AIR CONCENTRATIONS OF FIBERS IN THE VICINITY OF THE JOHNS-MANVILLE WASTE DUMP; DENISON, TEXAS

February 28, 1974
Weather Data during Sampling Period: Wind, Steady at 4.92 m/sec (11 mph) from the South to South-Southeast (150°-180°); Temperature, 17.2°C (63°F)

Sampling Data [1]				Fiber Concentration and Size Distribution by Optical Microscopy [2,4]					Fiber Concentration and Size Distribution by Electron Microscopy [3,4]					
Site Number	Sampling Elevation, m	Approximate Sampling Location with Respect to the Active Face of Waste Dump, m (ft)	Volume of Air Sampled, m^3	Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers				Total No. of Fibers per m^3	Size Distribution of Fibers by Length as a Percentage of the Total Number of Fibers				
					1.5-9.9 μm	10-19.9 μm	20-29.9 μm	>30 μm		0.048-0.06 μm	0.061-0.18 μm	0.181-0.36 μm	0.361-0.54 μm	0.541-1.49 μm
1	2	858 (2815) upwind	25.5	1.75×10^4	69	26	6	0	4.98×10^7	4	62	22	6	6
1	7	858 (2815) upwind	22.8	4.45×10^4	66	23	9	2	3.83×10^7	13	65	17	2	2
2	2	402 (1320) downwind	28.0	2.80×10^4	69	21	7	3	9.51×10^7	13	56	23	4	4
2	7	402 (1320) downwind	35.1	1.30×10^4	69	19	7	5	4.48×10^7	15	61	17	6	2
3	2	710 (2330) downwind	22.1	4.27×10^4	77	18	3	2	3.04×10^7	17	46	26	9	3
3	7	710 (2330) downwind	22.4	2.93×10^4	72	17	8	3	2.97×10^7	5	45	28	10	13

Samples were collected on 20.3 cm x 25.4 cm (8 in x 10 in) Millipore filters. The pore size was 0.8 μm and the effective filter area was 425.4 cm^2.

[1] Figure 14 is a location plot of the sampler locations at the sampling site.

[2] Phase contrast optics and a 4 mm objective lens were used for optical counting. The total magnification was 500X. The minimum fiber diameter included in the counts was estimated at 0.5 μm.

[3] Electron microscopy counting and sizing were done at a magnification of 16,364X. Fibers with a diameter as small as 0.016 μm were counted.

[4] Particles having an aspect ratio greater than 3:1 and approximately parallel sides were considered fibers.

The confidence level of the results is difficult to ascertain. The statistical distribution for the microscopy counting is ± 20%. The error associated with the measurement of the amount of air sampled is a maximum of ± 20%. This is based on the field flow meters and their calibration. Other errors associated with sample preparation, etc., cannot be accurately ascertained without a multiple regression analysis. Errors of this nature were assumed to be systematic and identical for all samples.

Results from the optical microscope analysis followed an anticipated trend. The highest values were noted at the Coalinga mill site where values in the order of 10^5 fibers per cubic meter were recorded. Denison gave values in the order of 10^4 fibers per cubic meter while Waukegan had the lowest values with an order of 10^2 fibers per cubic meter. This trend was anticipated because Coalinga had the highest visible emission rate and Waukegan had had recent heavy rain and frost.

The electron microscope analysis data did not show the same trend as for the optical microscope data. The highest ambient air concentrations were again found at the mill site in Coalinga, California, where values in the order of 10^8 fibers per cubic meter were noted. Waukegan gave values in the order of 10^7 fibers per cubic meter, while Denison gave values of 10^6 and 10^7 fibers per cubic meter on separate days. This is in contrast to the optical microscope data, where the Waukegan values were very much lower than Coalinga or Denison.

It is conjectured that the weather conditions would explain this apparent anomaly between the trends of the electron microscope and otpical microscope data. It is noted that Waukegan had experienced very heavy rain and then freezing conditions. The rain would scavenge the atmosphere, removing the suspended particles. The efficiency of the scavenging reduces dramatically with reduction in particle size of the particulates. For submicron particles, the efficiency is very low indeed. Again, once the particles had been removed from the general atmosphere, they would be bound to the earth trapped by the frozen water, which would prevent their redispersion. Thus, the larger fibers would be preferentially removed and would be prevented from being redispersed. In these terms, an increase in the ratio of smaller fibers is to be anticipated.

The fiber size distribution obtained by optical microscope analysis was similar for all the sites. The majority of the fibers, 65 to 75%, were in the size range of 1.5-10.0 μm, while 10 to 25% were in the size range of 10.0-20.0 μm. Some variance from these observations is to be found in the Waukegan data as a result of the very low fiber count (less than seven fibers per one hundred fields counted), which reduced the significance of the data.

The size distributions obtained from the electron microscope was not as consistent as the optical data. The most consistent size group was the 0.06 to 0.18 μm, where results varied between 45 to 60% in all of the samples. It was also observed that the number of fibers greater than 0.36 μm was a low percentage in all samples.

There are a number of factors which contribute to the size distribution of an ambient air aerosol size distribution. They include: 1) the weather conditions; 2) the nature of the source; 3) the proximity of other sources; and 4) the distance from the source to the monitoring station. These factors will combine in a complex manner to give rise to the resultant size distribution. In the light of the number of controlling factors, there is a high level of agreement in the data given, particularly at the broad level electron versus optical microscope observations.

AMBIENT AIR SAMPLES FROM AMBLER, PENNSYLVANIA

The objective of the EPA ambient air sampling program performed at Ambler, Pennsylvania was to determine whether asbestos waste disposal sites for manufacturing plants that use commercial asbestos are a major source of asbestos emissions. The method used was to isolate these sources from other sources of asbestos emissions and compare the isolated ambient concentrations that are generated by the waste disposal site to background ambient levels.

Ten sampler sites were chosen for the Ambler study. A map of the sampler sites described in the ESED, EPA report is reproduced in Figure 15.

Site No. 1 Sewage Disposal Plant -- Sampler site located approximately 305 m (1,000 ft) southeast of Nicolet's lagoon. With a northwest wind, emissions from Nicolet's and Certain-Teed's active pile can be measured. This site can also be used as a background during a southeasterly wind.

Site No. 2 Certain-Teed Active Pile Site -- Sampler site located on the northwest side of Certain-Teed active pile. With a southwesterly wind, the emissions from Certain-Teed active pile can be measured. With a northwesterly wind, the emission from the slope of the Nicolet pile can be measured. This site in conjunction with Sites No. 1 and No. 3 with a northwesterly wind can identify the emission from the Certain-Teed active pile.

Site No. 3 South Sector of Nicolet Pile -- Sampler and meteorological station site located on top of Nicolet active pile on the south sector. The site will measure the emissions from the lagoon on the top of the active pile with a north wind. With a south wind, emissions from the Certain-Teed

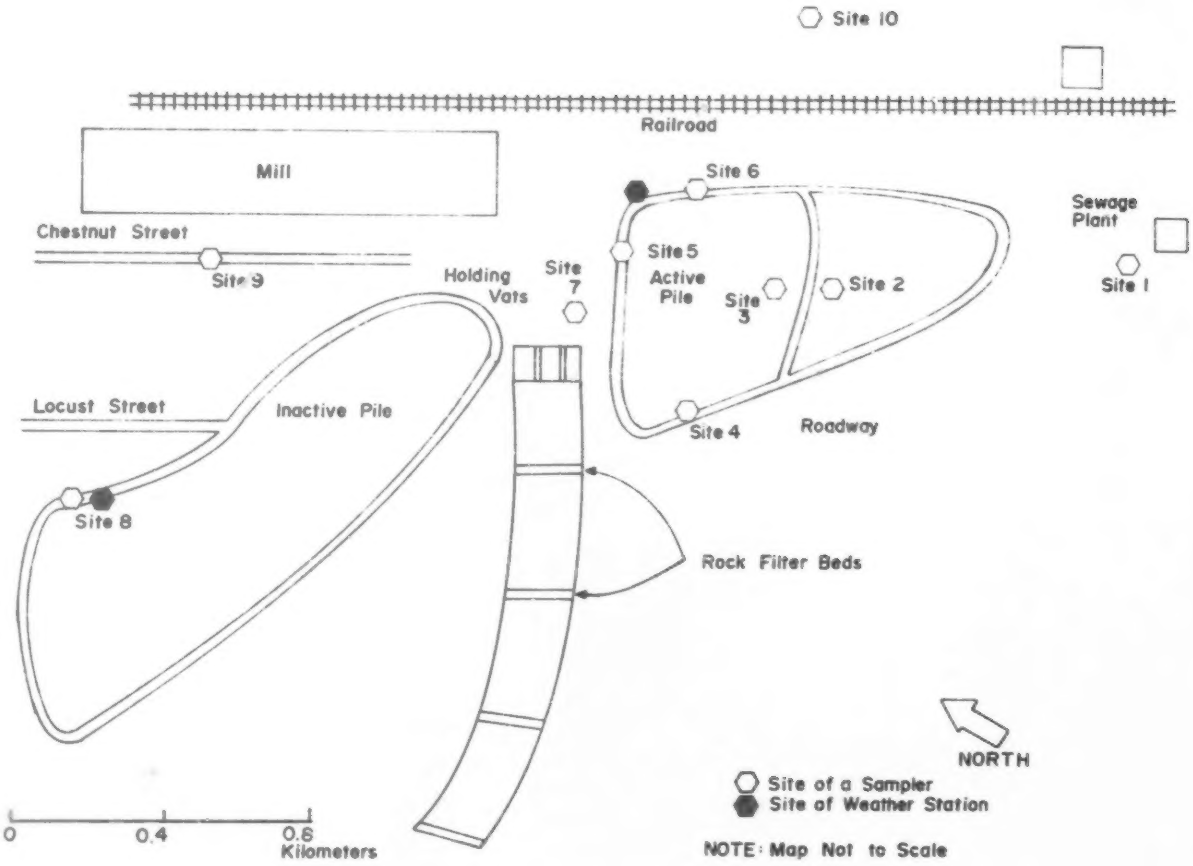

Site 10
Railroad
Mill
Site 6
Sewage Plant
Chestnut Street
Site 5
Active Pile
Site 9
Holding Vats
Site 7
Site 3
Site 2
Site 1
Locust Street
Inactive Pile
Site 4
Roadway
Site 8
Rock Filter Beds
NORTH
Site of a Sampler
Site of Weather Station
0
0.4
0.8
Kilometers
NOTE: Map Not to Scale

Figure 15. Sampler locations for ESED, EPA study, Ambler, Pennsylvania

Company can be further identified. The meteorological station will identify the wind speed and direction during this study.

Site No. 4 West Sector of Nicolet Pile -- Sampler site located on west sector of Nicolet active pile. With an east wind, emissions from lagoon on top of active pile can be measured.

Site No. 5 North Sector of Nicolet Pile -- Sampler site is located on north sector of Nicolet active pile. With a south wind, emissions from lagoon on top of active pile can be measured.

Site No. 6 East Sector of Nicolet Pile -- Sampler site is located on the east sector of Nicolet active pile. With a west wind, emissions from lagoon on top of active pile can be measured.

Site No. 7 Nicolet Settling Pond -- Sampler site is located at Nicolet settling ponds and will be operated downwind of emissions during dumping operation. This occurs at approximately 6:15 a.m. each day.

Site No. 8 Locust Avenue Site -- Sampler and meteorological station site is located at the foot of the north side of the Nicolet inactive pile in a playground on Locust Avenue. This site will measure emissions from the inactive pile in a residential area. Met station will identify directions of emissions.

Site No. 9 South Chestnut Street Site -- Sampler site is located in front yard of residence at 216 South Chestnut Street. With a southeast wind, the asbestos emissions can be measured at this site.

Site No. 10 Far East Site -- Sampler site is located at the corner of Main and Church Streets in a public park adjacent to an apartment complex. With a westerly wind, emissions from both plants can be measured in this residential area.

RESULTS FROM AMBLER PENNSYLVANIA

Ambient air samples were collected by the EPA on membrane filters with high-volume air samplers. The sampling periods varied from 30 minutes to 24 hours. Most of the samples, however, were collected for 12 hours. The filters were analyzed by Battelle Laboratories of Columbus, Ohio, using the method developed by Henry, et al[72]. This TEM analysis technique is described by Thompson[73] of the EPA as a semiquantitative determination of the mass of asbestos collected from a measured volume of ambient air. The method estimates the mass from the measured fiber length and breadth. A fiber of cylindrical form and an average density are assumed. The results of the analyses are reported in ng/m^3.

Typical results from the study are given in Table 10. Results cover the periods of 6:00 a.m. to 6:00 p.m on October 17, 1973, and October 18, 1973.

Table 10. AMBIENT AIR CONCENTRATIONS OF ASBESTOS FROM EPA STUDY AT AMBLER, PENNSYLVANIA

Sampling Site No.	Ambient Air Asbestos Concentrations (ng/m^3)	
	Samples Collected 6:00 am-6:00 pm October 17, 1973	Samples Collected 6:00 am-6:00 pm October 18, 1973
1	22	11
2	210	19
3	29	53
4	16	5.5
5	97	130
6	48	160
7	2,600*	1,200
8	7.2	12
9	23*	13*
10	210*	49*

* 24 hour sampling period ending at 6:00 pm

SECTION 7

TOPOGRAPHIC, DEMOGRAPHIC, AND METEOROLOGICAL DATA

TOPOGRAPHIC MAPS

Topographic maps in the 1:250,000 scale were obtained from the United States Geological Survey. The topography for a radius of 30 km is presented for the field sampling sites. Figure 16 shows the region near the Johns-Manville Asbestos Mine and Mill at Coalinga, California; Figure 17 shows the region near the Johns-Manville Asbestos Products Plant at Waukegan, Illinois; and Figure 18 shows the region surrounding the Johns-Manville Asbestos-Cement Pipe Plant at Denison, Texas. Although no outdoor sampling was done at the GAF Asbestos Mine and Mill at Eden Mills, Vermont, the topography of this area is included in Figure 19.

The topography of each of the field sampling sites is different. The Coalinga Asbestos Mine and Mill in California is in mountains which rise sharply above the nearby valley. The mountains are very rocky with steep slopes and sharp bends. The valleys are quite narrow.

The region surrounding the Johns-Manville Asbestos Products Plant at Waukegan, Illinois, is flat. Lake Michigan, on the east, presents a level surface. The land itself rises very slowly above the elevation of the lake.

Denison, Texas, the location of the Johns-Manville Asbestos Cement Pipe Plant, is in a region of low rolling

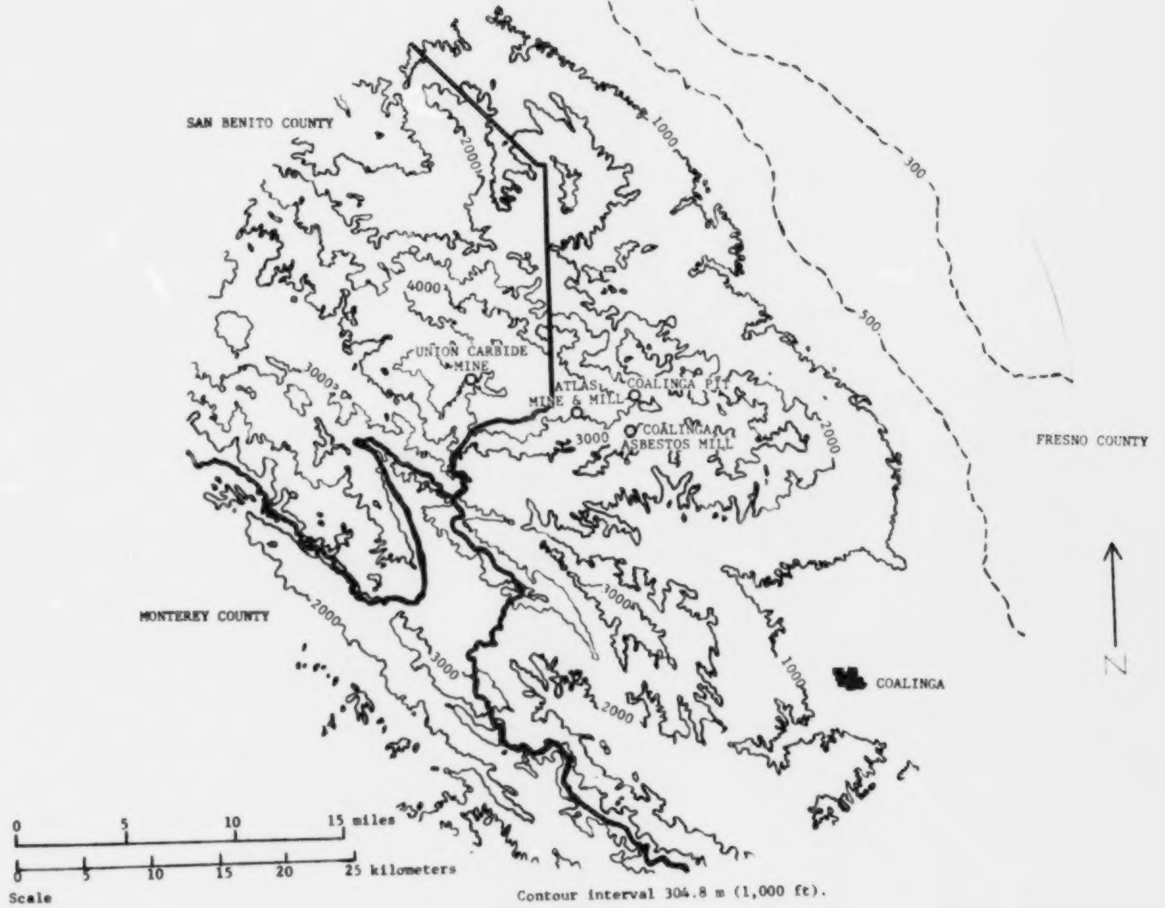

SAN BENITO COUNTY
FRESNO COUNTY
MONTEREY COUNTY
COALINGA
UNION CARBIDE MINE
ATLAS MINE & MILL
COALINGA PIT
COALINGA ASBESTOS MILL
300
500
1000
2000
3000
4000
N
0
5
10
15 miles
0
5
10
15
20
25 kilometers
Scale
Contour interval 304.8 m (1,000 ft).

Figure 16. Topographic map of the vicinity of the Johns-Manville asbestos mine and mill at Coalinga, California

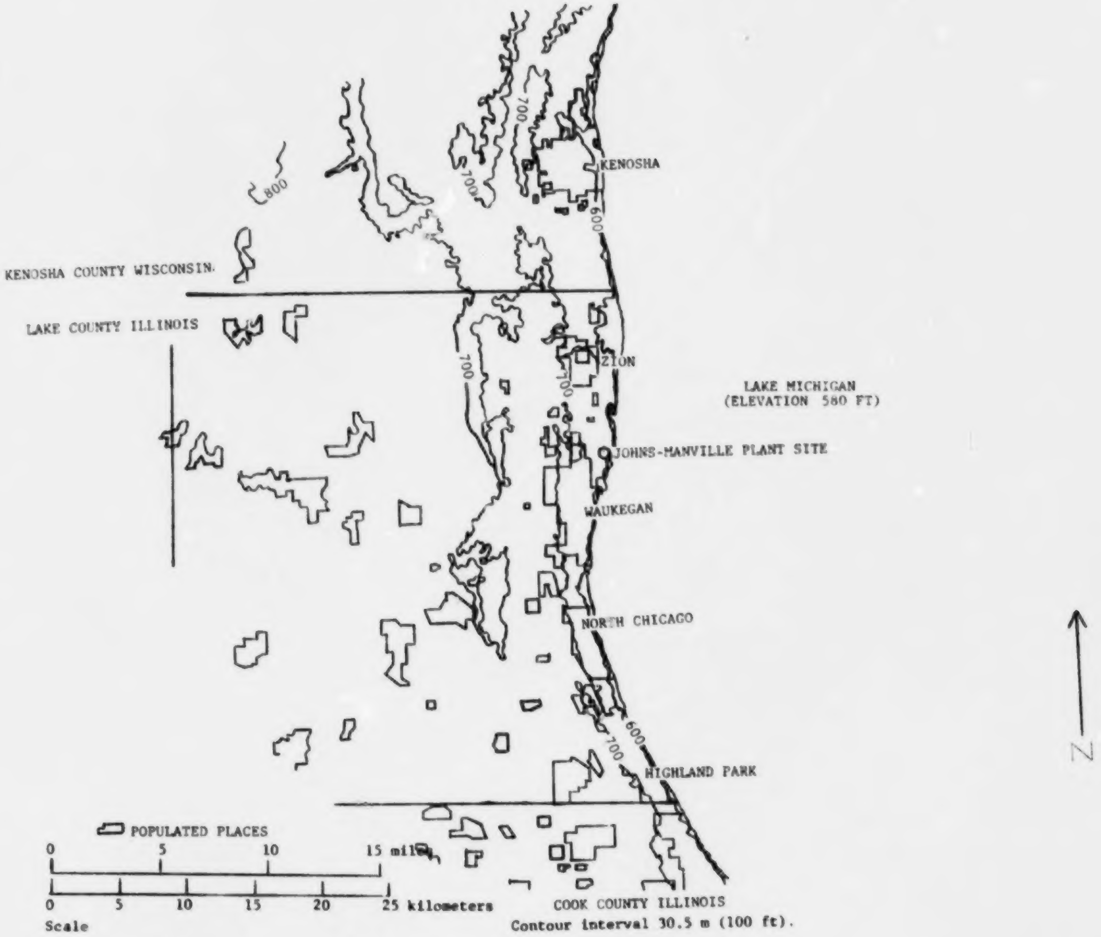
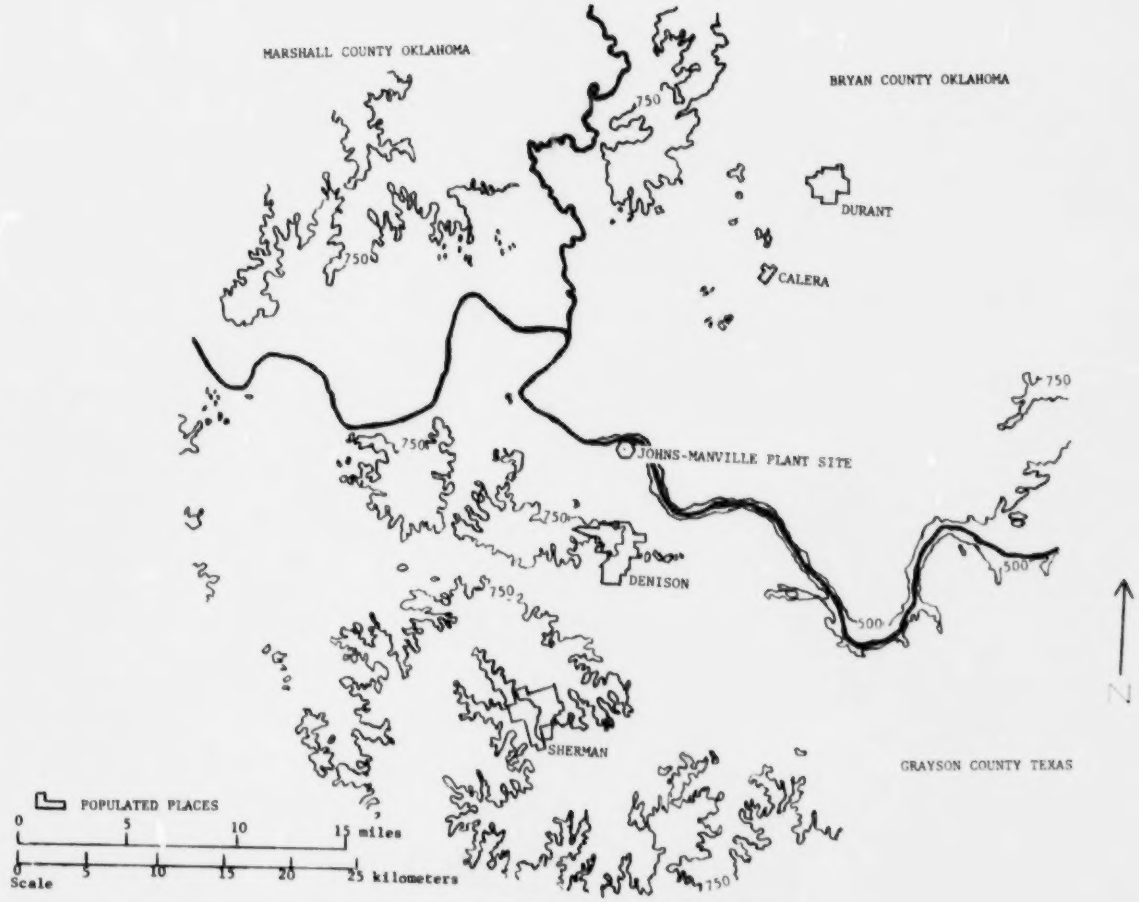

KENOSHA
KENOSHA COUNTY WISCONSIN
LAKE COUNTY ILLINOIS
ZION
LAKE MICHIGAN
(ELEVATION 580 FT)
JOHNS-MANVILLE PLANT SITE
WAUKEGAN
NORTH CHICAGO
HIGHLAND PARK
COOK COUNTY ILLINOIS
800
700
600
N
POPULATED PLACES
0
5
10
15 miles
0
5
10
15
20
25 kilometers
Scale
Contour interval 30.5 m (100 ft).

Figure 17. Topographic map of the vicinity of the Johns-Manville asbestos products plant at Waukegan, Illinois


MARSHALL COUNTY OKLAHOMA
BRYAN COUNTY OKLAHOMA
DURANT
CALERA
750
JOHNS-MANVILLE PLANT SITE
DENISON
SHERMAN
500
N
GRAYSON COUNTY TEXAS
POPULATED PLACES
0
5
10
15 miles
Scale
0
5
10
15
20
25 kilometers

Contour interval 76.2 m (250 ft).

Figure 18. Topographic map of the vicinity of the Johns-Manville asbestos cement pipe plant at Denison, Texas

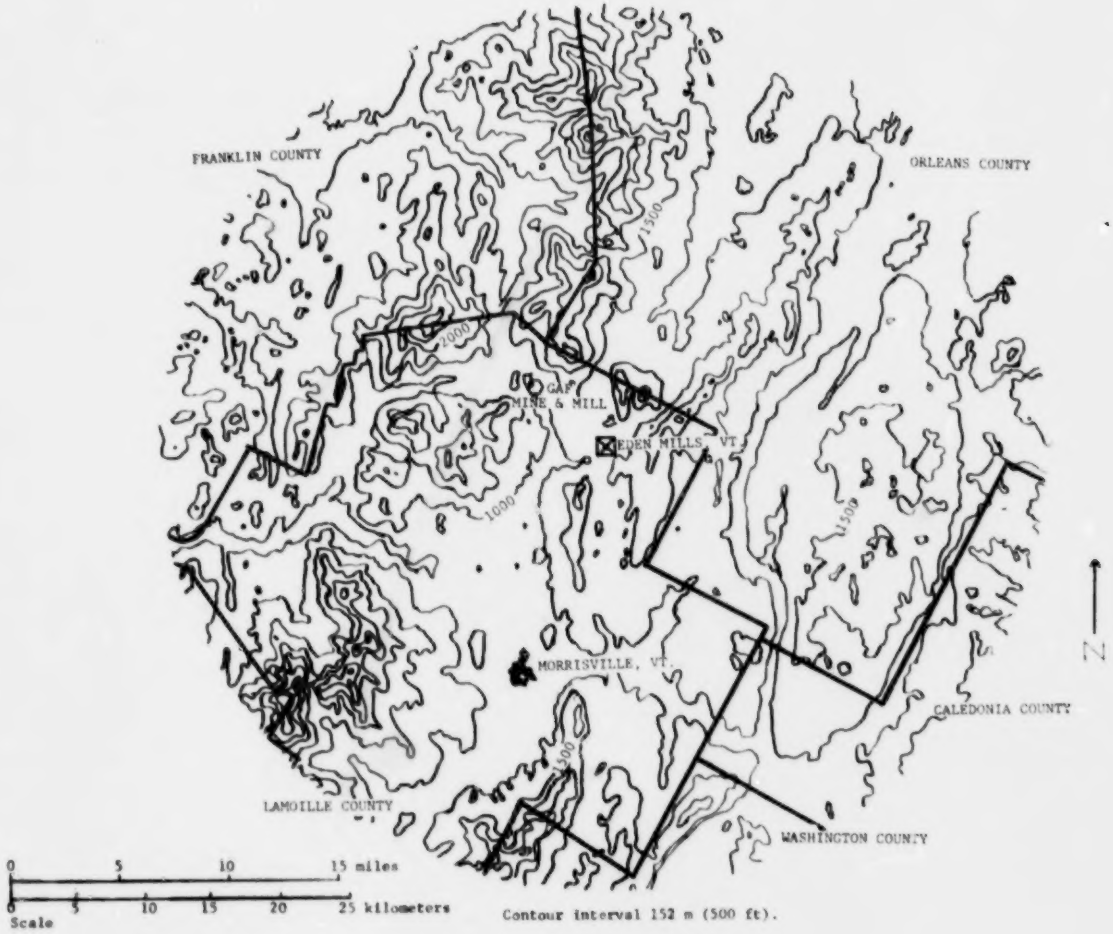

FRANKLIN COUNTY
ORLEANS COUNTY
GAF MINE & MILL
EDEN MILLS, VT.
MORRISVILLE, VT.
CALEDONIA COUNTY
LAMOILLE COUNTY
WASHINGTON COUNTY
N
2000
1500
1000
1500
1500
0
5
10
15 miles
0
5
10
15
20
25 kilometers
Scale
Contour interval 152 m (500 ft).

Figure 19. Topographic map of the vicinity of the GAF asbestos mine and mill at Eden Mills, Vermont

hills. The Red River runs through a valley among the hills. This valley is not very depressed in elevation nor adjoined by steep slopes. This topography is a "middleground" between the mountains near Coalinga, California, and the flatlands at Waukegan, Illinois.

Topographic data was not supplied with the EPA, Ambler data; however, it was found that the area is substantially flat.

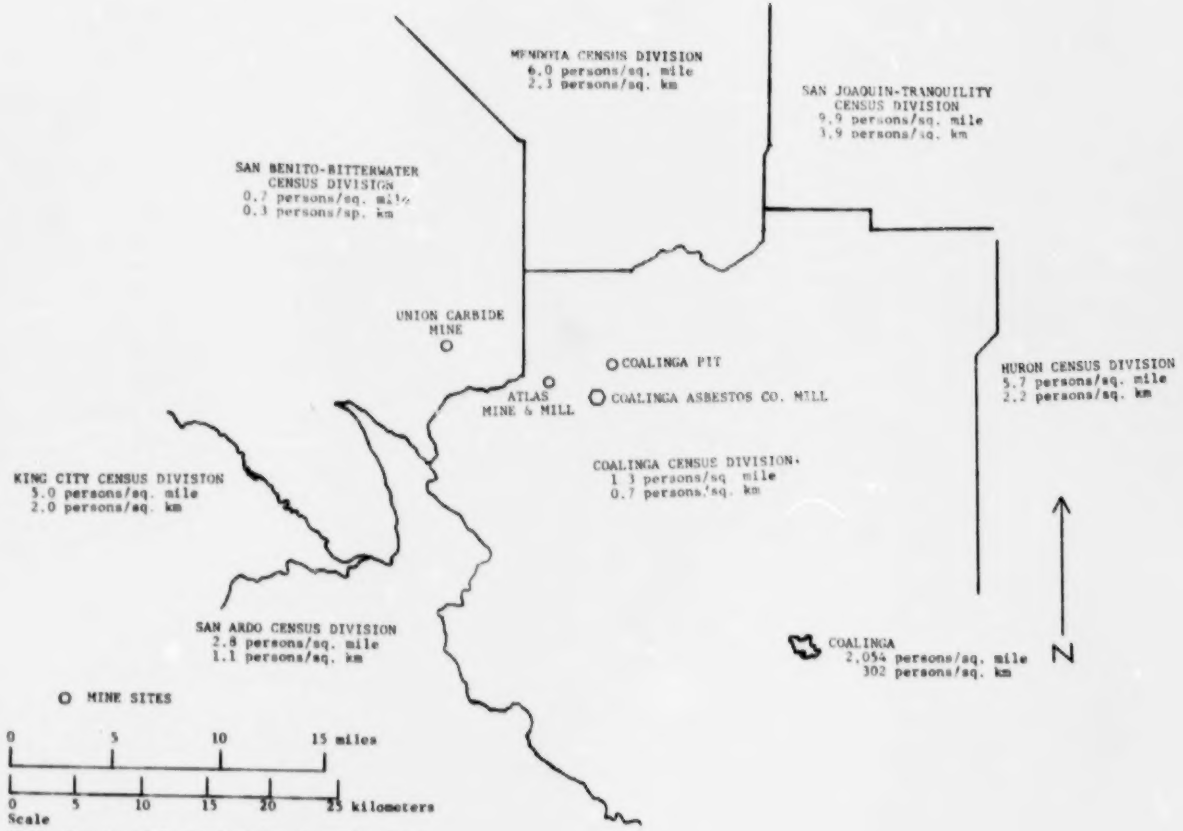
DEMOGRAPHIC MAPS

Population data on cities, towns, and counties was obtained from the United States Census Bureau. This data was compiled and is presented for a radius of 30 km surrounding the field sampling sites. The maps were prepared in the 1:250,000 scale and are shown; 1) in Figure 20 for the region around Coalinga, California; 20 in Figure 21 for the vicinity of Waukegan, Illinois; 3) in Figure 22 for the locale of Denison, Texas; and in Figure 23 for Ambler, Pennsylvania.

The four maps show the extreme remoteness of the mine at Coalinga, California, as contrasted to the asbestos processing plants. Both Waukegan, Illinois, and Denison, Texas, are urban; but, show extreme population density differences. Waukegan, Illinois, is part of a major center of population in contrast to the low population density at Denison, Texas.

METEOROLOGICAL DATA

Data for the Surface Wind Roses was obtained from the National Climatic Center at Ashville, North Carolina. The data requested was for the nearest weather station for which records are maintained. Table 11 lists the location of interest, i.e., the site of the asbestos plants, and the actual site where the weather readings were taken.


MENDOTA CENSUS DIVISION
6.0 persons/sq. mile
2.3 persons/sq. km
SAN JOAQUIN-TRANQUILITY
CENSUS DIVISION
9.9 persons/sq. mile
3.9 persons/sq. km
SAN BENITO-BITTERWATER
CENSUS DIVISION
0.7 persons/sq. mile
0.3 persons/sp. km
UNION CARBIDE
MINE
COALINGA PIT
ATLAS
MINE & MILL
COALINGA ASBESTOS CO. MILL
HURON CENSUS DIVISION
5.7 persons/sq. mile
2.2 persons/sq. km
KING CITY CENSUS DIVISION
5.0 persons/sq. mile
2.0 persons/sq. km
COALINGA CENSUS DIVISION
1.3 persons/sq. mile
0.7 persons/sq. km
N
SAN ARDO CENSUS DIVISION
2.8 persons/sq. mile
1.1 persons/sq. km
COALINGA
2,054 persons/sq. mile
302 persons/sq. km
MINE SITES
0
5
10
15 miles
0
5
10
15
20
25 kilometers
Scale

NOTE: Density of Census Division is rural density.

Figure 20. Demographic map of the vicinity of the Johns-Manville asbestos mine and mill at Coalinga, California

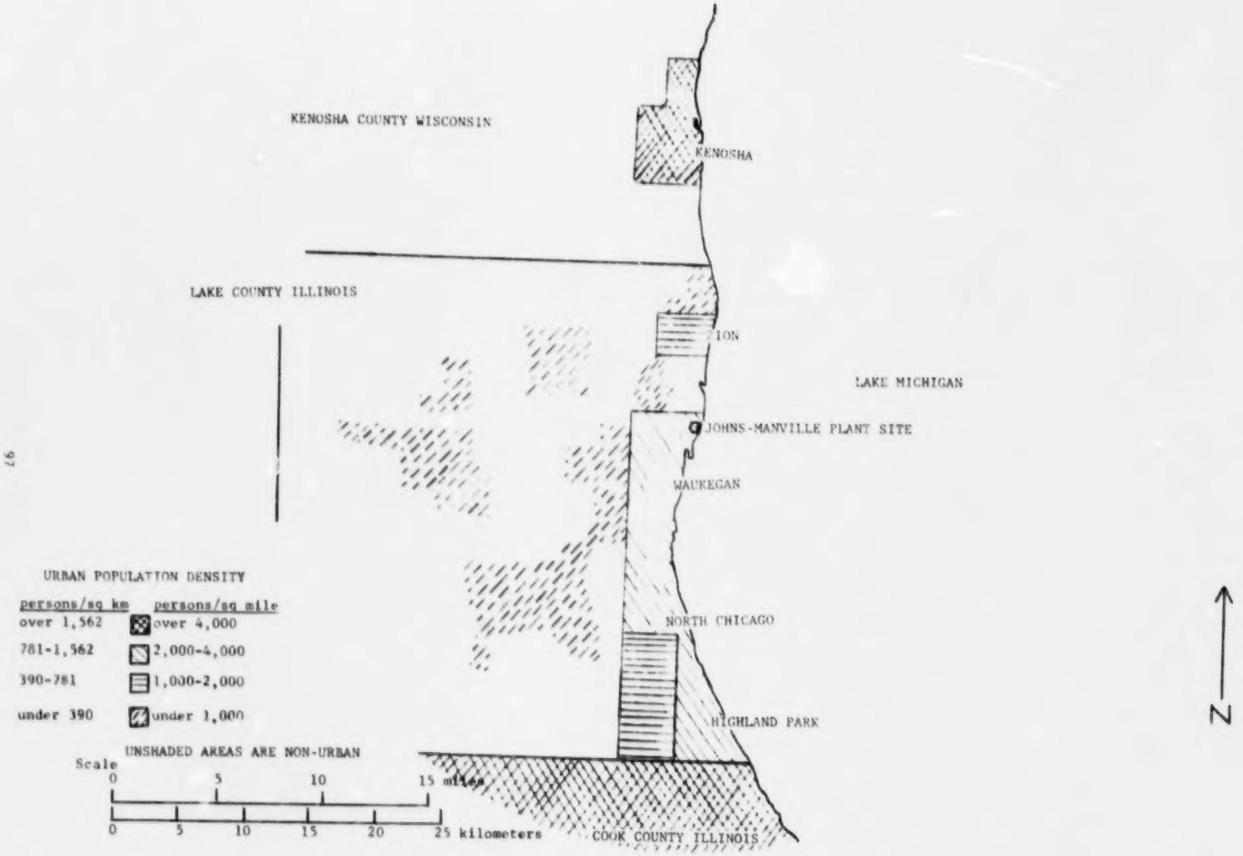
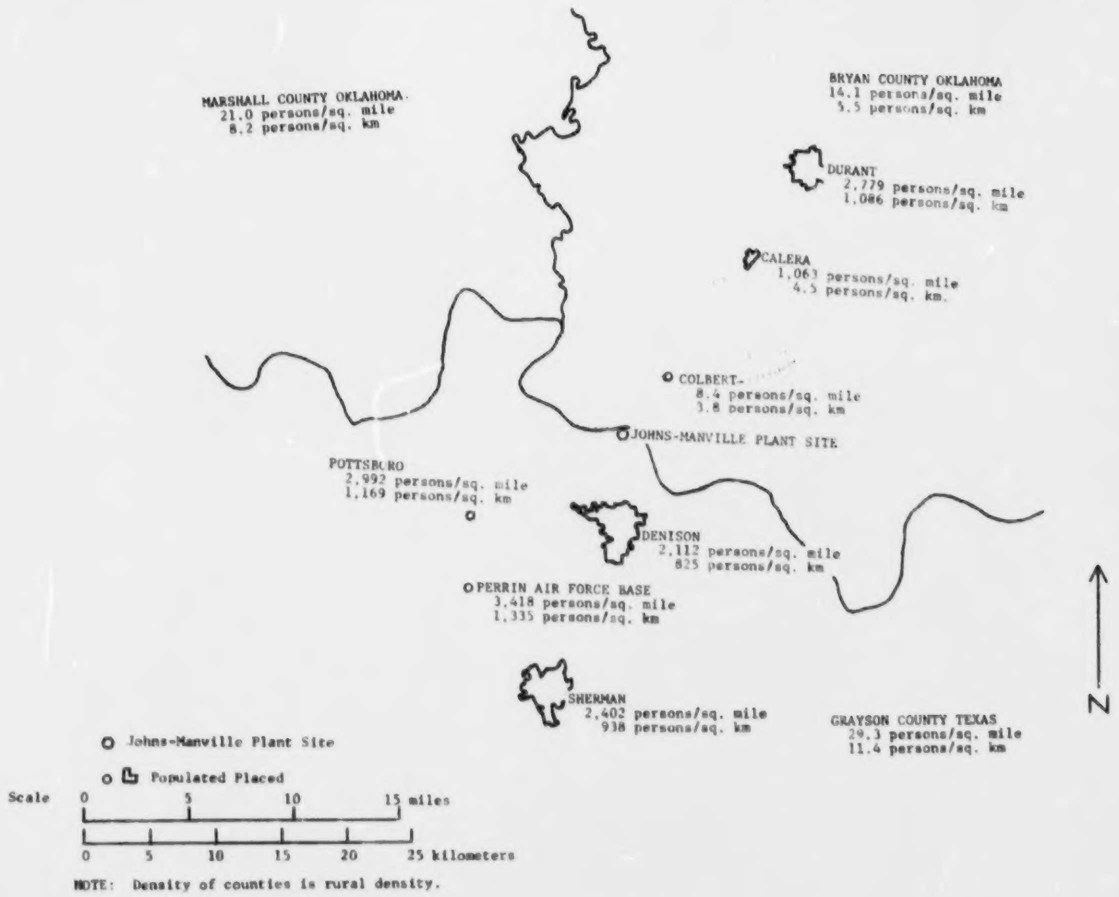

KENOSHA COUNTY WISCONSIN
KENOSHA
LAKE COUNTY ILLINOIS
ION
LAKE MICHIGAN
JOHNS-MANVILLE PLANT SITE
WAUKEGAN
NORTH CHICAGO
HIGHLAND PARK
COOK COUNTY ILLINOIS
N
URBAN POPULATION DENSITY
persons/sq km
persons/sq mile
over 1,562
over 4,000
781-1,562
2,000-4,000
390-781
1,000-2,000
under 390
under 1,000
UNSHADED AREAS ARE NON-URBAN
Scale
0
5
10
15 miles
0
5
10
15
20
25 kilometers

Figure 21. Demographic map of the vicinity of the Johns-Manville asbestos products plant at Waukegan, Illinois



MARSHALL COUNTY OKLAHOMA
21.0 persons/sq. mile
8.2 persons/sq. km
BRYAN COUNTY OKLAHOMA
14.1 persons/sq. mile
5.5 persons/sq. km
DURANT
2,779 persons/sq. mile
1,086 persons/sq. km
CALERA
1,063 persons/sq. mile
4.5 persons/sq. km.
COLBERT-
8.4 persons/sq. mile
3.8 persons/sq. km
JOHNS-MANVILLE PLANT SITE
POTTSBORO
2,992 persons/sq. mile
1,169 persons/sq. km
DENISON
2,112 persons/sq. mile
825 persons/sq. km
PERRIN AIR FORCE BASE
3,418 persons/sq. mile
1,335 persons/sq. km
SHERMAN
2,402 persons/sq. mile
938 persons/sq. km
GRAYSON COUNTY TEXAS
29.3 persons/sq. mile
11.4 persons/sq. km
N
Johns-Manville Plant Site
Populated Placed
Scale
0
5
10
15 miles
0
5
10
15
20
25 kilometers

NOTE: Density of counties is rural density.

Figure 22. Demographic map of the vicinity of the Johns-Manville asbestos-cement pipe plant at Denison, Texas

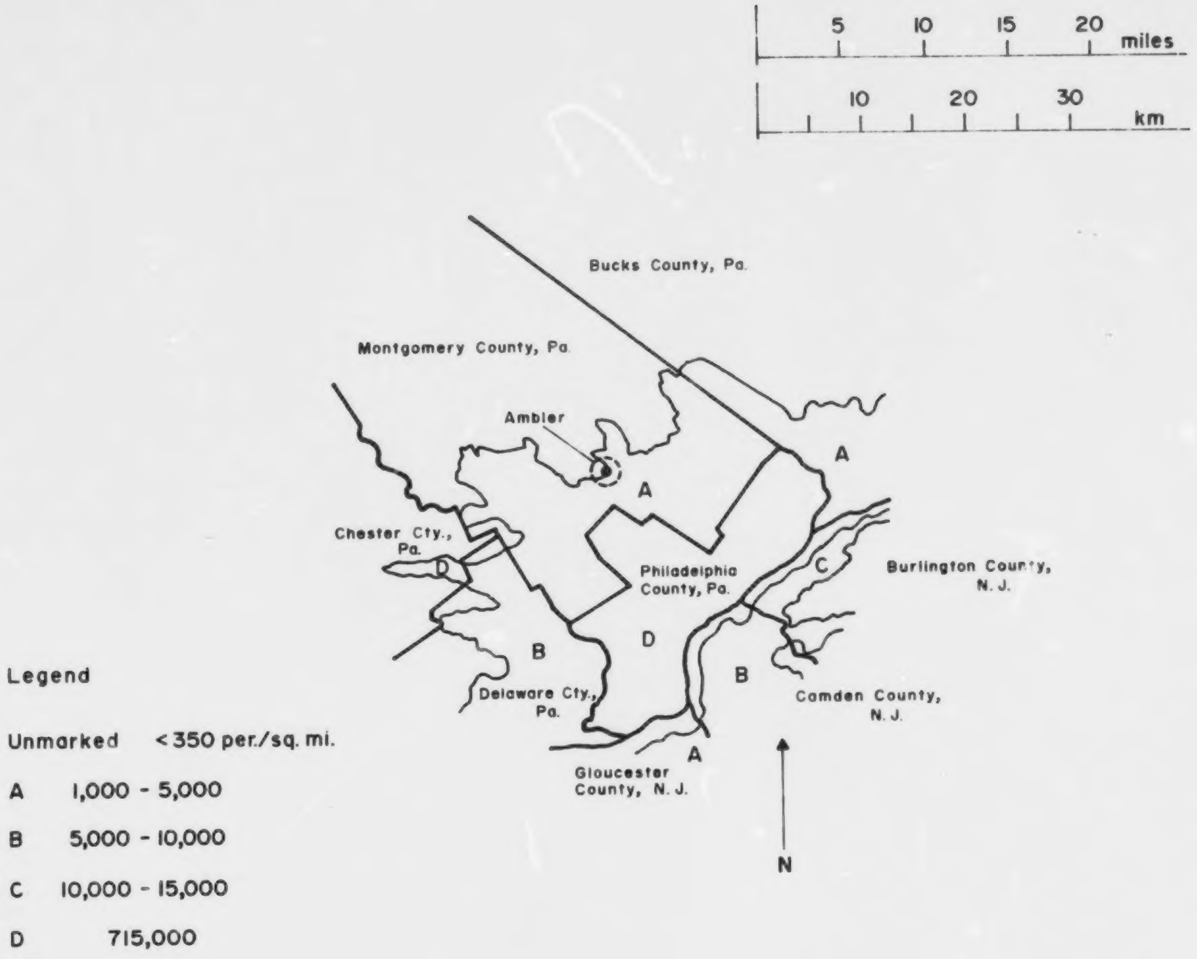

5
10
15
20
miles
10
20
30
km
Bucks County, Pa.
Montgomery County, Pa.
Ambler
A
A
Chester Cty., Pa.
D
Philadelphia County, Pa.
C
Burlington County, N. J.
D
B
B
Delaware Cty., Pa.
Camden County, N. J.
A
Gloucester County, N. J.
N
Legend
Unmarked <350 per./sq. mi.
A 1,000 - 5,000
B 5,000 - 10,000
C 10,000 - 15,000
D 715,000

Figure 23. Demographic map of the vicinity of Nicolet, Certain-Teed asbestos products plant at Ambler, Pennsylvania

Table 11. WIND ROSE SOURCES

Location of Interest	Location of Weather Station
Coalinga, California	Stockton, California
Waukegan, Illinois	Waukegan, Illinois
Denison, Texas	Sherman, Texas
Eden Mills, Vermont	Burlington, Vermont
Gila County, Arizona	Phoenix, Arizona
Ambler, Pennsylvania	Philadelphia, Pennsylvania

The surface wind roses are presented in Appendix D. For each site, three wind roses are drawn; 1) January, 2) July, and 3) Annual. The January and July wind roses indicate semi-annual differences in the wind parameters. The most noticeable example is Stockton, California. The January wind rose shows that the winds were calm 13.1% of the time and blew from the east to southeast a total of about 30% of the time. In July, the winds were calm only 4.7% of the time and less than 1% of the time were winds blowing from the east to southeast.

Meteorological data is usually gathered at airports and cannot always be assumed to be representative of the local region of interest. This is especially true of the mountainous region near Coalinga, California. Stockton, California, is situated in the valley. The local topography surrounding the mine and mill has a domineering effect on meteorological parameters. The deep valleys will channel winds, cause turbulence, and create thermal gradients; hence, a description of the local winds at Coalinga should be measured at the site.

SECTION 8

THE SIGNIFICANCE OF ASBESTOS EMISSIONS FROM OPEN SOURCES

INTRODUCTION

The preliminary asbestos emission data obtained at the Coalinga, Waukegan, and Denison sites, and the data from Ambler supplied by the EPA, gave information on the concentration of fibers to be found in the ambient air at or near to these sites. To assess the ambient air concentration of fibers in a general area extending outward from these sites, the EPA's Climatological Dispersion Model (CDM) was used. This model is described in the ensuing text.

The model enabled a series of isopleths to be drawn which give the predicted fiber concentration as a function of distance from the source. Super-imposed on to geographical maps, the area exposed to a given concentration is seen. Demographic data, also on the map, indicate the exposure levels of the local population.

There are as yet no ambient air exposure levels accepted by either federal, state, or local authorities because of a lack of medical data. During the course of this study, a safe ambient air exposure level was suggested at the request of the EPA. This level is presented, along with other proposed standards which were subsequently published in the literature.

SUGGESTED AMBIENT AIR ASBESTOS EXPOSURE STANDARDS

Concentration isopleths as such are of little value unless they can be related to a medical health standard. Unfortunately, no such health standard has been agreed upon by the scientific and medical communities. For the purposes of this study only, and at the specific request of the EPA, a value of 500 fibers/m^3 was taken as a level above which non-occupational exposure could be considered harmful to health. There is no medical evidence to support this level. It was derived from OSHA occupational exposure limits in the following manner.

The Occupational Health and Safety Act (OSHA) lists a time weighted average (TWA) limit of 2 fibers per cubic centimeter (a fiber is defined as having an aspect ratio of 3 to 1 and a length greater than 5 microns). This limit was effective July 1974. A peak limit of 10 fibers/cc for any 15 minute period is also listed. This occupational index is based on medical evidence related to the development of asbestosis during a 50 year working lifetime. The limit also assumes the standard 40 hour working week. For the general populace, the ambient exposure consists of 168 hours per week. In addition, the risk factor should be reduced by a factor of at least 10^3. Thus,

$$(2 \text{ fibers/cc}) \times \frac{40 \text{ hrs}}{168 \text{ hrs}} \times 10^{-3} \times \frac{10^6 \text{ cc}}{m^3} \approx 500 \text{ fibers/m}^3$$

The use of this numerical standard is cautioned. The OSHA regulation is based on incidences of asbestosis not cancer. Many uncertainties and anomalies are found in the literature on the exposure to asbestos and the incidences of cancer. It is possible that for the development of cancer, a degree of susceptability is requisite. Some people appear to be affected by even the lowest exposure levels, while others are unaffected by high exposure.

Two recommendations for ambient air standards have been proposed in recent publications. The Illinois Institute for Environmental Quality[74] has proposed a maximum level of 1,000 fibers/m^3 based on a 24-hour average; they also recommend that a maximum 2-hour average concentration of 1,500 fibers/m^3 should not be exceeded more than once in a 24-hour period or more than 30 times per year.

The Connecticut Department of Environmental Protection has also proposed an ambient air standard[75]. Their standard of 30 nanograms per cubic meter can be approximated to a 1/1000 of the OSHA standard for occupational exposure of 2 fibers/cc when time weighted for a 24-hour, 7-day per week exposure.

The Illinois and Connecticut proposed standards are both based on mortality rates projected from available medical data. It is stressed than these exposure levels are proposed -- not accepted.

CLIMATOLOGICAL DISPERSION MODEL

The EPA's Climatological Dispersion Model (CDM) determines the long-term (seasonal or annual) quasi-stable pollutant concentration at a ground level receptor. It uses average emission rates from point or area sources, and a joint frequency distribution of the wind direction, wind speed, and stability for the same period. This model is available in computer program form on a time-sharing basis from the Computer Sciences Corporation. The user's guide to this model was written by A.D. Busse and J.R. Zimmerman[76]. An introduction to the theory of the model is given in Appendix C.

The determination of the quasi-stable pollutant concentration at any ground level receptor is obtained by calculating explicit values for the transport and decay of the pollutant during its time aloft. Transport is determined by a complex interaction of wind direction and velocity variables as well as others; all are continuous variables. For calculational simplicity, it is better to consider only a small number of discrete ranges for each of the variables. Thus, windspeed, for instance, is divided into the intervals 0 to 3, 4 to 6, 7 to 10, 11 to 16, 17 to 21, and > 21 knots per hour. Similarly, there are 16 wind direction classes (22.5 degrees each) and 6 stability classes as well as 6 windspeed classes for a total of 576 combinations -- and no further detail. This class structure allows for the definition of a simple correlation function, Φ, between the three sets of variable classes. That is, Φ relates the frequencies with which the various combinations occur (i.e., wind NNE at 3.05 to 6.10 m/sec with stability class 4, etc.).

The calculation of the transport itself is accomplished via a Gaussian plume model which can accommodate an exponential decay rate of the pollutant with time. The spread of the plume is internally parameterized in terms of the stability class. An initial value for the standard deviation for the vertical dispersion can be specified. This parameter reflects the topography of the source area.

Some other degrees of freedom (inputs) are: the height of the mixing layer, the height of the smokestack (if any), and the geographical distribution of the emitters.

A cartesian coordinate block map is superimposed on the physical map of the region. Sources (point and/or area) are identified by their coordinates and are assigned their emission rates. Calculation proceeds additively, with the emission rates and weather conditions assumed stable for about one hour periods. Fluctuations are not included. The points at which the pollutant output are desired are specified via separate input and are available either printed as a table or on cards, in a format suitable for calcomp interfacing.

Some program modifications were required. Specifically, a modification was required to accommodate input windspeed ranges in units of miles per hour rather than knots (conversion to m/sec is done internally). An additional change altered the printout to eliminate scaling problems.

It should be noted that the model does not allow for pollutant interactions (i.e., fiber agglomeration or breakdown) and that no effects due to the size distribution of the fibers can be calculated. Finally, experience with the model has shown that its predictions are generally high, often by as much as 200%. However, there is a provision in the model for calibrating it by making simultaneous emission and sampling measurements and obtaining a regression relation between the model predictions and the sampling results. The technique has had good results, and the calibration measurements need not be performed on the same pollutant as the one to be modelled, i.e., SO_2 dispersion data can be used to calibrate the asbestos dispersion model.

CLIMATOLOGICAL DISPERSION MODEL INPUT DATA

The information required for the dispersion model input is the area source size, the number of areas, the class wind speed, the stability class, and the source term. The values taken for each source are given in Table 12. Since this study was only a preliminary study to evaluate the significance of emissions from waste dumps, no attempt was made to subject every ambient air measurement to dispersion model analysis. Instead, one set of data was utilized from each of the four sites.

Table 12. STABILITY CLASSES
(From Ref. 77)

Surface Wind Speed (at 10 m) m/sec	Day			Night	
	Incoming Solar Radiation			Thinly Overcast or > 4/8 Low Cloud	≤ 3/8 Cloud
	Strong	Moderate	Slight		
< 2	A	A-B	B	----	---
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

The source size and the number of areas were determined from the site survey. The class wind speed is related to the measured wind speed. and is found from the appropriate table (see Table C2, Appendix C). The stability class is a function of the wind speed, the solar radiation conditions, and the amount of cloud cover. It is determined by observing the meteorological conditions and then referring to a reference chart (see Table 13).

The source term is derived from the ambient air measurement taken at the site in terms of fibers per cubic meter. Two conditions were established for the selection of the ambient air value used: one was that it was a downwind sample, and two was that it represented the worst case of the samples taken. In this manner, the maximum extent of population exposure could be estimated. The ambient air concentration at the downwind sampling station is then related back to the source emission in terms of fibers emitted per second. The method used is described by Turner[77]. In this method, square area sources are considered as line sources with a Gaussian distribution. The method of computation is outlined briefly below:

- Determine the stability class from the wind speed and incoming solar radiation conditions observed at the time that the sample was taken.
- Calculate the initial standard deviation in the horizontal direction, σ_{y_o}.

$$\sigma_{y_o} = \text{side}/4.3$$

- Use σ_{y_o} and the graphs in Turner's handbook to get x_o, the distance to a pseudo point source.
- Add x, the sample-source distance, to x_o and use the appropriate graph to obtain σ_y.
- Use x and the graphs to get σ_z.

Table 13. INPUT DATA FOR THE CLIMATOLOGICAL DISPERSION MODEL

		Coalinga	Waukegan	Denison	Ambler
Measured ambient air asbestos concentration (fibers/m^3)	OM	9.51×10^5	2.48×10^2	2.80×10^4	5.2×10^4
	EM	5.93×10^8	6.07×10^7	9.51×10^7	2.6×10^7
Area source size		100 m x 100 m	150 m x 150 m	210 m x 210 m	167 m x 167 m
No. of area sources		4	3	1	1
Class wind velocity* (m/sec)		6.93	6.93	4.92	4.92
Stability class		D	D	B	C
Calculated source term emission rate (fibers/sec)	OM	1.65×10^{10}	7.64×10^6	1.29×10^9	3.02×10^8
	EM	1.03×10^{13}	1.87×10^{12}	4.37×10^{12}	1.51×10^4

OM = measured by optical microscope
EM = measured by electron microscope

* class wind velocity obtained from measured velocity and reference to Table C2 in Appendix C.

- The source term is then calculated from

$$Q = X\pi\sigma_y\sigma_z U$$

where Q = source term emission rate, fibers/sec

X = measured ambient air asbestos concentrations, fibers/m^3

σ_y, σ_z = the standard deviation in the y and z directions, respectively

U = wind velocity, m/sec

The assumption is made that the entire area source emits fibers homogeneously at a constant rate.

The computer program also requires that the area source be described as squares on an emission grid map with each square having its own emission source term.

For the Ambler data, taken by the EPA, the worst case data, taken at site number 7, gave an ambient concentration of 2,600 ng/m^3. This value was converted to give the approximate numbers of fibers equivalent to the mass. For conversion to fibers of optical microscope size, the factor suggested by the Engineering Equipment Users Association (EEUA)[76] was used, where 1 fiber ≡ 0.05 ng. This gave a total of 5.2 x 10^4 fibers/m^3 greater than 5 μm. Conversion to electron microscope sized fibers can be approximated by using the factor suggested by Thompson[77], where 104 fibers ≡ 1 ng. This gives a total of 2.6 x 10^7 fibers/m^3 for fibers below 5 μm.

(The above figures are only approximate because the conversion factors are only approximate. Further, the size distribution of the collected sample is not known and, therefore, that part of the total mass which should be assigned to a given conversion factor is not known. However, the largest error would result from the selection of a conversion factor which can vary with the fiber size from 1 fiber ≡ 10^{-6} ng.

Nicholson[17], to 1 fiber ≡ 0.5 x 10^{-1} ng, EEUA[70]. For this reason, the comparatively small error introduced by using the total mass as representing each size fraction has been ignored.)

CLIMATOLOGICAL DISPERSION MODEL RESULTS

The ambient air concentrations of asbestos were calculated at every kilometer on a 60 km by 60 km grid with the source at its center. The tabular computer output was transferred to a grid and isopleths were drawn. These isopleths were superimposed onto demographic maps to show the extent of the general population exposure.

These maps with the isopleths are shown for Coalinga, California; Waukegan, Illinois; Denison, Texas; and Ambler, Pennsylvania, in Figures 24, 25, 26, and 27, respectively. The ambient air concentrations of asbestos fibers which are 1.5 μm and above are low in comparison to those fibers below 1.5 μm. The difference is usually three or four orders of magnitude.

At a distance of approximately 1 kilometer from the source, the proposed standard of 500 fibers per cubic meter greater than 5 μm is only exceeded at two locations, Denison and Coalinga. However, the number of fibers less than 1.5 μm is very high, and, in all instances, is of the order of a million fibers per cubic meter.

The CDM model was unreliable beyond about 10 km. At 10 km from the source, the 500 fibers per cubic meter was exceeded in only one location, Coalinga. The numbers of fibers less than 1.5 μm at a distance of 10 km from the source were found to be 1.6 x 10^6, 4.5 x 10^4, 2.4 x 10^5, and 4.5 x 10^3, respectively, for the Coalinga, Waukegan, Denison, and Ambler locations.

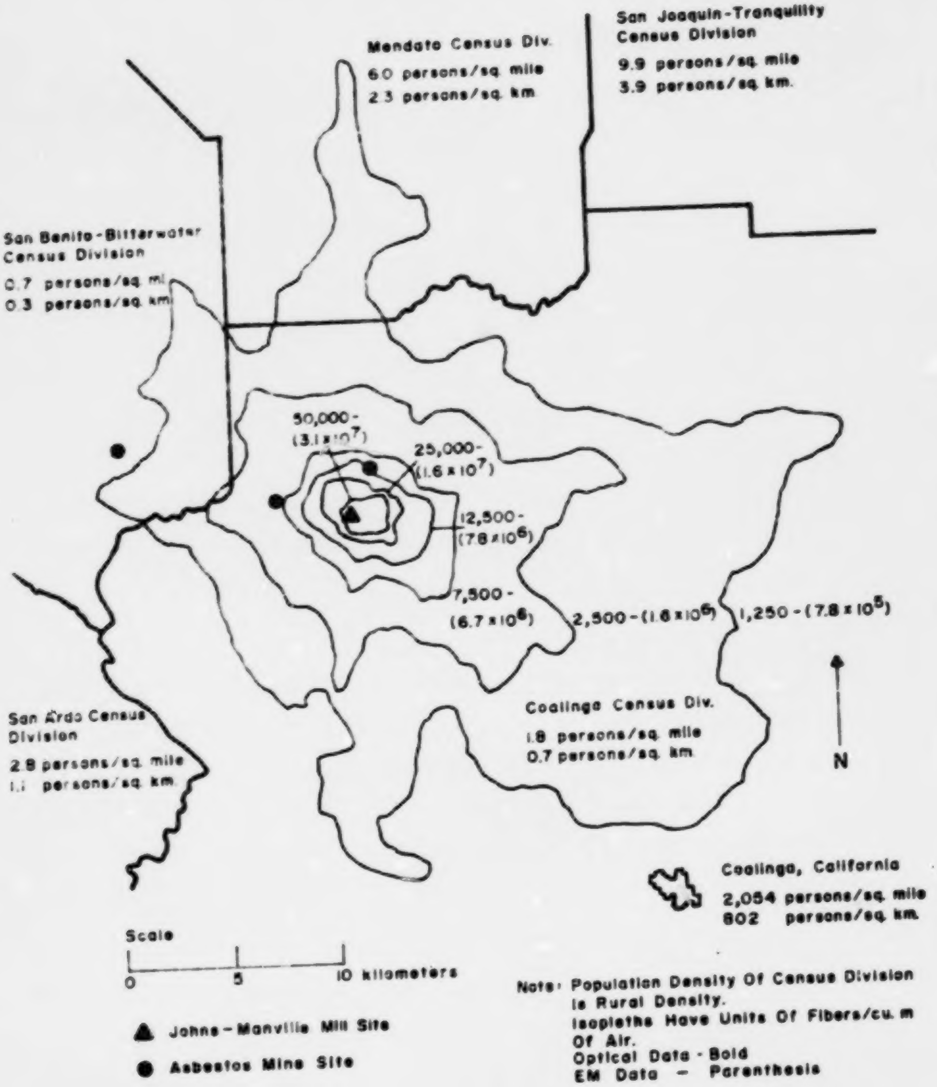

Mendota Census Div.
6.0 persons/sq. mile
2.3 persons/sq. km
San Joaquin-Tranquility Census Division
9.9 persons/sq. mile
3.9 persons/sq. km.
San Benito-Bitterwater Census Division
0.7 persons/sq. mi.
0.3 persons/sq. km
50,000-(3.1×10⁷)
25,000-(1.6×10⁷)
12,500-(7.8×10⁶)
7,500-(6.7×10⁶)
2,500-(1.6×10⁶)
1,250-(7.8×10⁵)
San Ardo Census Division
2.8 persons/sq. mile
1.1 persons/sq. km
Coalinga Census Div.
1.8 persons/sq. mile
0.7 persons/sq. km
N
Coalinga, California
2,054 persons/sq. mile
802 persons/sq. km
Scale
0
5
10 kilometers
Johns-Manville Mill Site
Asbestos Mine Site
Note: Population Density Of Census Division is Rural Density.
Isopleths Have Units Of Fibers/cu. m Of Air.
Optical Data - Bold
EM Data - Parenthesis

Figure 24. Asbestos fiber concentration isopleths for Coalinga, California

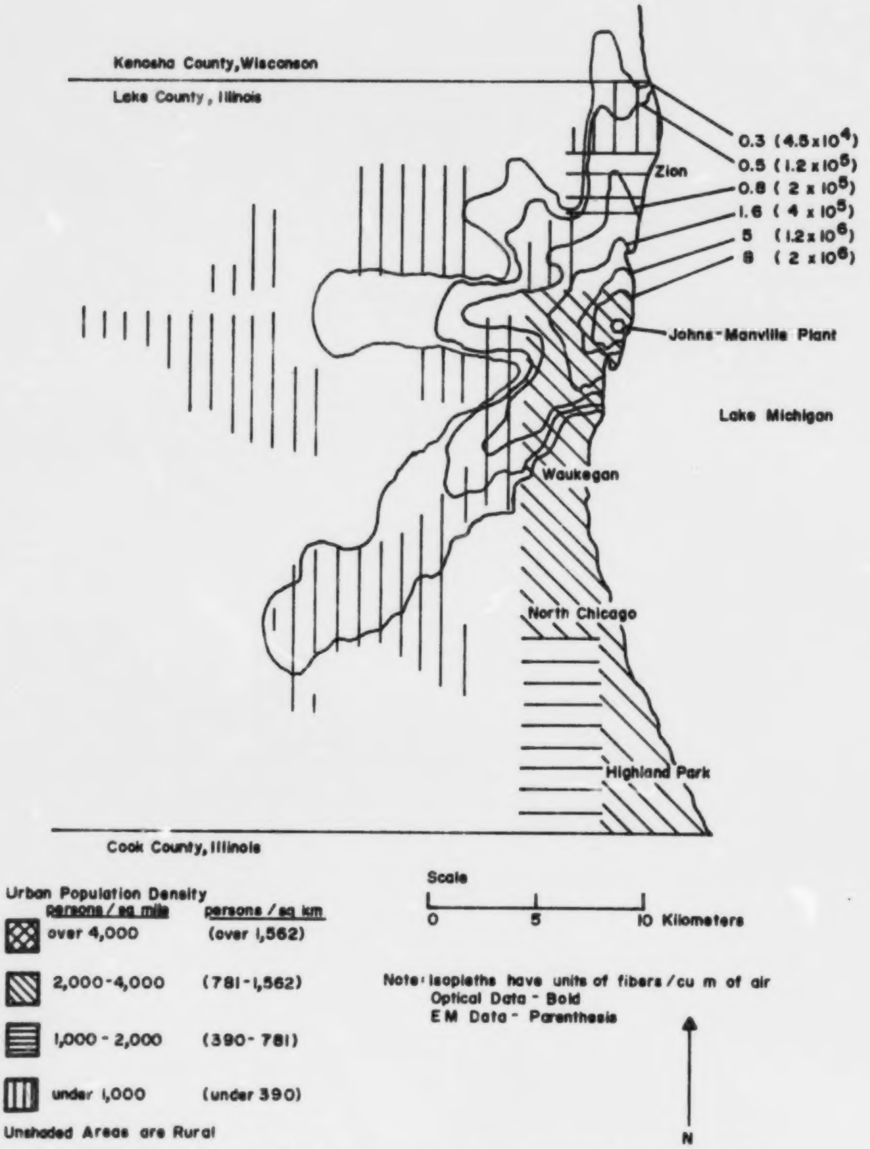

Kenosha County, Wisconson
Lake County, Illinois
0.3 (4.5 x 10^4)
0.5 (1.2 x 10^5)
0.8 (2 x 10^5)
1.6 (4 x 10^5)
5 (1.2 x 10^6)
8 (2 x 10^6)
Zion
Johns-Manville Plant
Lake Michigan
Waukegan
North Chicago
Highland Park
Cook County, Illinois
Urban Population Density
persons / sq mile
persons / sq km
over 4,000 (over 1,562)
2,000-4,000 (781-1,562)
1,000 - 2,000 (390- 781)
under 1,000 (under 390)
Unshaded Areas are Rural
Scale
0
5
10 Kilometers
Note: isopleths have units of fibers / cu m of air
Optical Data - Bold
E M Data - Parenthesis
N

Figure 25. Asbestos fiber concentration isopleths for Waukegan, Illinois

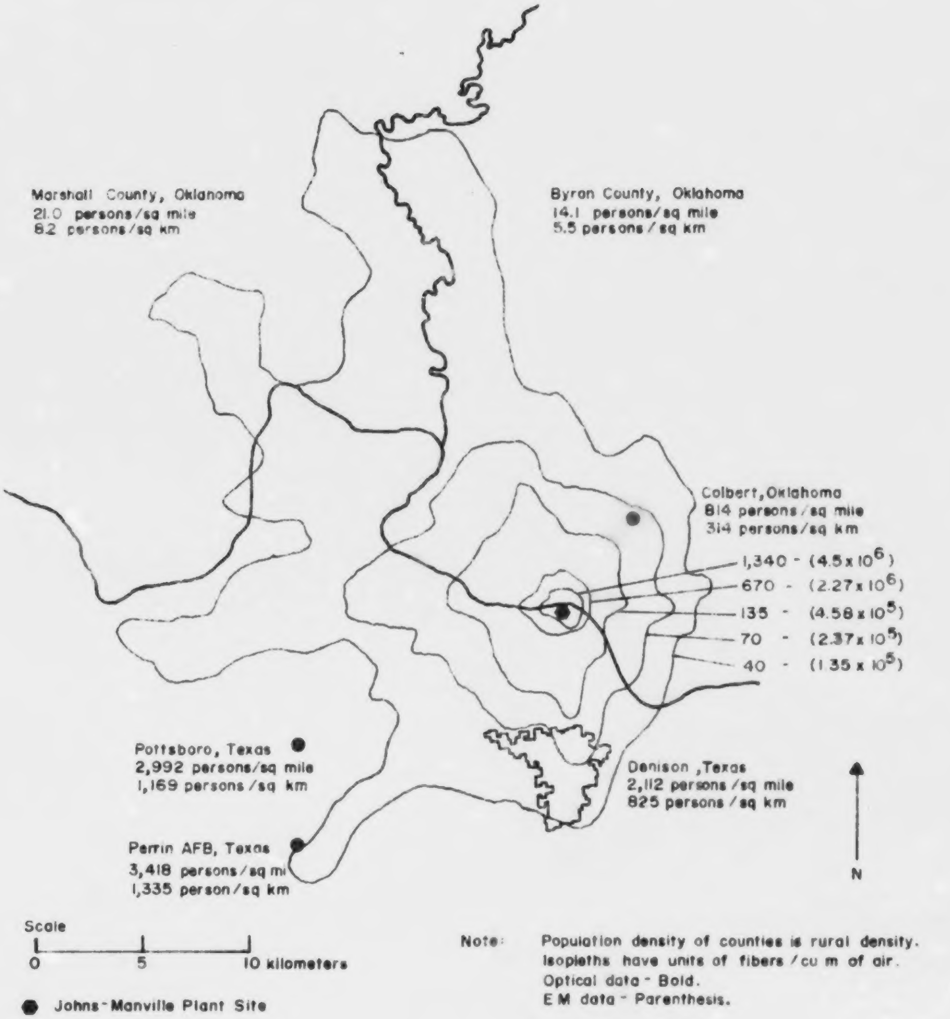
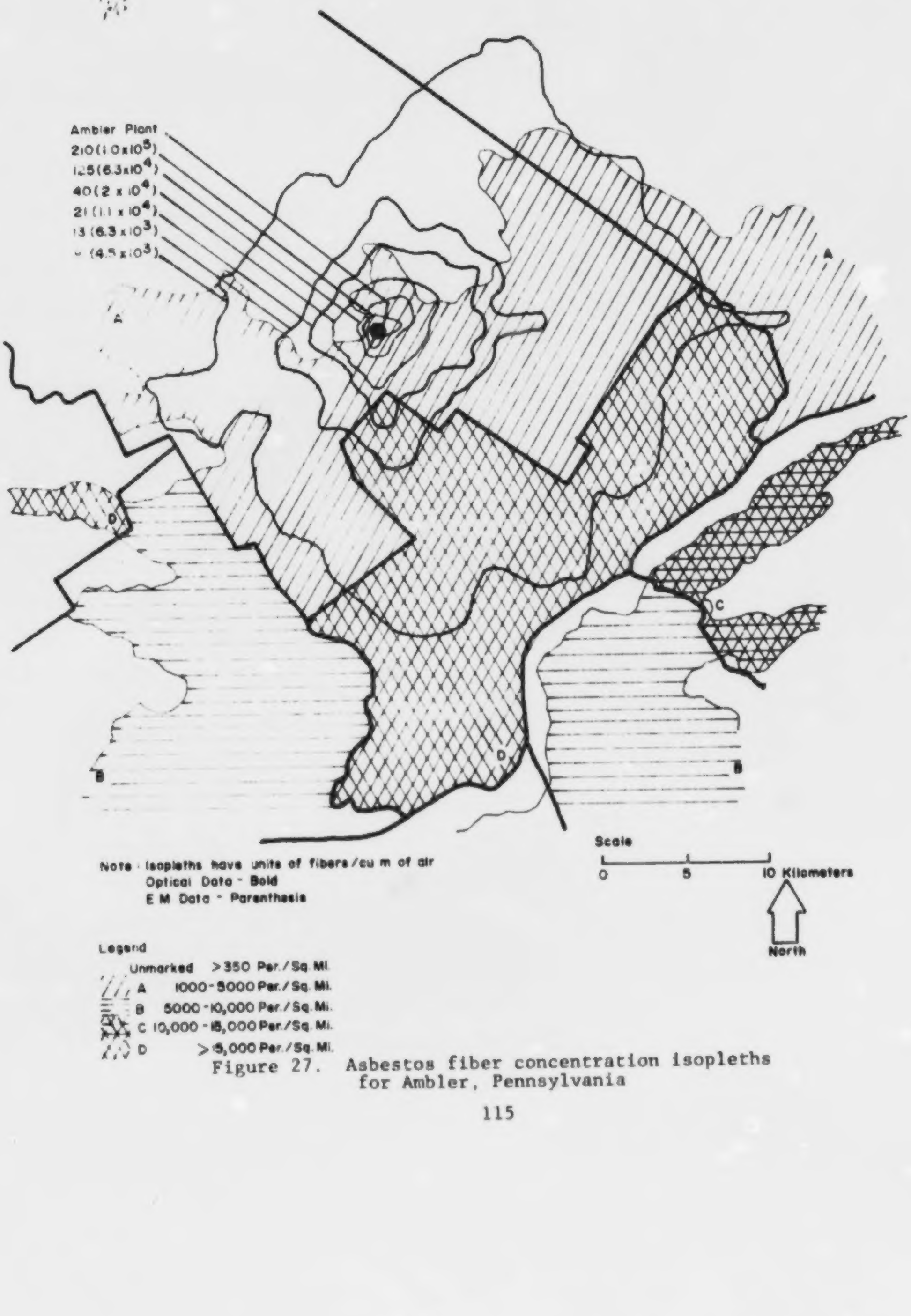

Marshall County, Oklahoma
21.0 persons/sq mile
8.2 persons/sq km
Byron County, Oklahoma
14.1 persons/sq mile
5.5 persons/sq km
Colbert, Oklahoma
814 persons/sq mile
314 persons/sq km
1,340 - (4.5 x 10^6)
670 - (2.27 x 10^6)
135 - (4.58 x 10^5)
70 - (2.37 x 10^5)
40 - (1.35 x 10^5)
Pottsboro, Texas
2,992 persons/sq mile
1,169 persons/sq km
Denison, Texas
2,112 persons/sq mile
825 persons/sq km
Perrin AFB, Texas
3,418 persons/sq mi
1,335 person/sq km
N
Scale
0
5
10 kilometers
Johns-Manville Plant Site
Note: Population density of counties is rural density.
Isopleths have units of fibers/cu m of air.
Optical data - Bold.
EM data - Parenthesis.

Figure 26. Asbestos fiber concentration isopleths for Denison, Texas



Ambler Plant
210(1.0x10⁵)
125(6.3x10⁴)
40(2 x 10⁴)
21(1.1 x 10⁴)
13(6.3 x 10³)
- (4.5 x 10³)
A
A
D
C
D
B
B
Scale
0
5
10 Kilometers
North
Note - Isopleths have units of fibers/cu m of air
Optical Data - Bold
E M Data - Parenthesis
Legend
Unmarked >350 Per./Sq.Mi.
A 1000-5000 Per./Sq.Mi.
B 5000-10,000 Per./Sq.Mi.
C 10,000-15,000 Per./Sq.Mi.
D >15,000 Per./Sq.Mi.

Figure 27. Asbestos fiber concentration isopleths for Ambler, Pennsylvania

It is concluded, therefore, that exposure to fibers of greater than 1.5 μm is at a low level, while exposure to fibers of less than 1.5 μm is high. Until the vital issue of the medical significance of small fiber exposure is resolved, it would be premature to suggest that these conditions are safe or constitute a non-occupational health hazard. The resolution of the medical question will undoubtedly be some years away. Until such time, it would be prudent to study the practicality of abating these emissions.

DISCUSSION OF THE USE OF THE CLIMATOLOGICAL DISPERSION MODEL

The CDM was designed primarily for large area sources and multiple point sources. It was the design of the model that the receptor points be at distances near the sources, i.e., the radial distance to the receptor be the same order of magnitude as the area source size. The present use of the CDM was completely opposite. The receptor was at a minimum distance of a kilometer from the source, while the largest source term dimension was 210 meters square. The problems of the CDM for this type of use are inherent in the model itself.

The major difficulty with the model is the way it calculates emissions from an area source. An angular segment of 22½° centered at the receptor point is divided in 20 equal parts. Along each radial line of these segments, the program queries at set radial distances (defined in Table C4 of the manual) to search for the area source. Once found, the concentration is calculated. This search technique is the major source of error. As radial distances increase, the arc lengths increase, hence the area source could lie entirely between the radial lines and never be found, resulting in a zero output. Where only part of the area source is located, an underestimate of the concentration value results.

For point sources, a direct calculation between the receptor and source is made. This would eliminate zero output. An equivalent "point source" for each area source was calculated and used as input to obtain better isopleths. A division by zero occurred in the subroutine which calculates the effective source height. This type of error halts calculation of the concentration at the receptor point. Elimination of this division by zero requires a study of the CDM computer program itself. Such a task was beyond the scope of this project.

The resulting isopleths at the larger radial distances were extrapolated through zero output where possible. The outermost isopleth is probably an underestimate of the ambient air concentration of asbestos fiber because of this extrapolation.

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SECTION 10

APPENDICES

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> This report reviews and summarizes information on prevention and suppression of dust in mining, tunneling, and quarrying published in the United States from 1961 through 1967. Unpublished pertinent data developed or assembled by the Bureau of Mines during this period also are included.

Anonymous

Putting a Wet Blanket on Dust.
Minerals Processing, May, pp. 4-8 (1972).

> A combination of water and surfactant is sprayed at points of dust generation to suppress dust. The Chem-Jet spray system is described. The compound surfactant should be miscible with water at all temperatures, free-flowing, of uniform viscosity, non-corrosive, non-toxic, and non-inflammable when used with the mineral being processed.
>
> A spraying system is described along with its costs.

Anonymous

Spray System Solves Dust Problems at Arundel Quarry.
Pit and Quarry, 65, No. 7, pp. 82-84 (1973).

> The installation of the Chem-Jet spray system is described. This system sprays water with a surfactant, compound MR at points of dust generation. The results shows satisfactory dust suppression.

Anonymous

Stabilizing Mine Dumps.
Mining Magazine, 119, No. 4, pp. 296-299 (1968).

> Up to the end of 1967, a total of R2,631,000 had been spent by mines of the South African Chamber on covering dumps with vegetation, rock or other material to prevent the emission of dust. Of this R1,408,000 was

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spent on vegetation, R1 million of it being through the Vegetation Unit which has so far covered 3,000 acres. The present average cost, taking into account the wide variety of conditions -- no two dumps or dams are completely alike -- works out at R250 per acre. The eventual cost of treating all gold mine dumps and dams will be plus R7 million at present prices.

Anonymous

Surface Mining and Reclamation; A Boost with Bigger, Better Machines.
Coal Age, 77, No. 3, pp. 96-97 (1972).

> A conscientious effort to do a better reclamation job than that required by law characterizes the surface mining program of a progressive Ohio coal producer. Not resting on past achievements in reclamation, Anthony Mining has intensified efforts. The addition of a 524-fwhp Allis-Chalmers HD-41 crawler tractor will boost current and future mining and reclamation efforts.

Anonymous

Ventilating Open Pit Mines During Blasting.
Mining Magazine, August, p. 163 (1973).

> Description of Type NK-12KV Ventilator-Sprinkler. This turbo-propeller device is useful in suppressing dust. Tests show that at a water consumption of 180 m^3/hr the solid content of the air during and shortly after a blast is reduced from 8.4 mg/m^3 to 2.4 mg/m^3 in 28 minutes. After 15 minutes, the solid content had dropped to 3.5 mg/m^3.

Asbestosis Research Council

Recommended Code of Practice for the Handling and Disposal of Asbestos Waste Materials.
Thomas Jenkins, Ltd., London (1973).

> Procedures which satisfy the Asbestos Regulations of 1969 for the disposal of asbestos containing waste are listed. These recommended practices will protect both the worker and the general populace from ambient air exposure of asbestos.

Asbestosis Research Council

Code of Practice for Handling Consignments of Asbestos Fibre in British Ports.
Thomas Jenkins, Ltd., London (1969). Revised 1973.

> Procedures which satisfy the Asbestos Regulations of 1969 during stevedore operations at dockside are described. These practices consider not only the safety of the workers but also minimize the exposure of the general populace to asbestos in the ambient air.

Asbestosis Research Council

Technical Note No. 1: The Measurement of Airborne Asbestos Dust by the Membrane Filter Method.
Thomas Jenkins, Ltd., London (1970).

> The membrane filter method for determining the concentration of asbestos in the air is described. Method of sample collection and typical types of equipment are detailed. Lab mounting of the collected sample and counting by optical microscopy is described. Finally, evaluation of the sample relating the fiber count to the ambient air concentration is illustrated. The asbestos regulations are presented for comparison of field results.

Asbestosis Research Council

Technical Note No. 2: Dust Sampling Procedures for use with the Asbestos Regulations 1969.
Thomas Jenkins, Ltd., London (1971).

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Asbestosis Research Council

Control and Safety Guide No. 1: Protective Equipment in the Asbestos Industry (Respiratory Equipment and Protective Clothing).
Thomas Jenkins, Ltd., London (1973).

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The types of respiratory equipment, their cleaning and maintenance, and sources of suppliers are listed. The types of protective clothing, the methods of cleaning, and suppliers of such clothing are listed. Accomodations for changing from protective clothing to street clothes without contaminating the workers personal garments are described.

Asbestosis Research Council

Control and Safety Guide No. 2: The Application of Sprayed Asbestos Coatings.
Thomas Jenkins, Ltd., London (1972).

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Asbestosis Research Council

Control and Safety Guide No. 3: Stripping and Fitting of Asbestos-Containing Thermal Insulation Materials.
Thomas Jenkins, Ltd., London (1973).

This guide describes the regulations which cover the thermal insulation industry when using asbestos-containing materials. Procedures for minimizing asbestos dust emissions from the following operations: the stripping of old insulation, the installation of new insulation, the handling and storage of materials, and site hygiene are outlined.

Asbestosis Research Council

Control and Safety Guide No. 4: Asbestos Textile Products, CAF/Asbestos Beater Jointings and Asbestos Millboard.
Thomas Jenkins, Ltd., London (1971).

This guide covers general regulations and practices such as good housekeeping, proper handling and storage of materials and waste disposal. Specific operations for which procedures are recommended to abate asbestos dust emissions are: the use of asbestos cloth in the manufacture of protective clothing and fire protection materials; the use of asbestos cloth in mattress making; the use of asbestos cloth in thermal insulation; the use of asbestos rope lagging for thermal insulation; and the use and fabrication of asbestos millboard.

Asbestosis Research Council

Control and Safety Guide No. 5: Asbestos-Based Materials for the Building and Shipbuilding Industries and Electrical and Engineering Insulation.
Thomas Jenkins, Ltd., London (1973).

This guide contains recommended procedures for working with the following asbestos-based materials; corrugated and flat sheets, and all ancillary asbestos cement building materials; rainwater, soil, flue pipes, and cisterns; moulded and extruded building products; asbestos insulating board and asbestos wallboards; high density asbestos cement and resinated laminates used in electrical engineering; water and sewer pipes; and asbestos felt and paper. The recommended practices cover the following operations: cutting and machining using both power and hand tools; sanding; drilling; punching; filing; and cleaning. Hoods for power tools are illustrated and some suppliers are listed.

Asbestosis Research Council

Control and Safety Guide No. 6: Handling, Storage, Transportation, and Discharging of Asbestos Fibre into Manufacturing Process.
Thomas Jenkins, Ltd., London (1971).

The guide presents recommended practices covering the operations of handling, storage, transport, and discharge of the asbestos fiber into the manufacturing process that will reduce asbestos emissions. Exhaust ventilation, use of respirators, use of protective clothing, waste disposal, and general hygiene and good housekeeping are among the practices recommended.

Asbestosis Research Council

Control and Safety Guide No. 7: The Control of Dust by Exhaust Ventilation when Working with Asbestos. Thomas Jenkins, Ltd., London (1973).

> Typical dust control system for control of asbestos dust emissions are described. Dust control systems normally consist of (1) hooding, (2) ducting, (3) dust collector; and (4) fans. Each component of the system is described with several examples illustrated. Costs of systems are given.

Asbestosis Research Council

Control and Safety Guide No. 8: Asbestos Based Friction Materials and Asbestos Reinforced Resinous Moulded Materials. Thomas Jenkins, Ltd., London (1970).

> This guide cites practices which would minimize asbestos dust emissions when working with the following materials: asbestos based friction materials both moulded and woven which are available in (a) roll, sheet, or pad form, (b) liners or facings, drilled and undrilled, and (c) the above materials bonded or rivetted to components; and asbestos reinforced resinous moulded materials which are available in (a) sheet, rod, or tube form, (b) machined components to specifications of customer, and (c) moulded components to customer's requirements. Operations to which these products are subjected to are: cutting, grinding, linishing, drilling, milling, sanding, turning, and routing.

Asbestosis Research Council

Control and Safety Guide No. 9: The Cleaning of Premises and Plant in Accordance with the Asbestos Regulations. Thomas Jenkins, Ltd., London (1973).

> The Asbestos Regulations require cleanliness of premises and plants using asbestos and asbestos-containing materials. Recommended procedures for satisfying this law are presented for the cleaning of floors, walls, machinery and equipment, overhead structures, and waste disposal. Types of vacuum cleaning equipment are described and some suppliers are listed.

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Open-Pit Mining.
Mining Annual Review, June, pp. 155-173 (1971).

Review of the open-pit mining industry. The economics of the scale of mining are tremendous with many factors to be considered. New equipment, financing trends, and mine planning are discussed. The impact of environmental pressures on the open pit mining industry, both present and future, are reviewed.

Bauer, Alan

Current Drilling and Blasting Practices in Open Pit Mines.
Mining Congress Journal, 58, No. 3, pp. 20-27 (1972).

The trend in the mining industry to large rotary drills has continued and percussive drills have largely been replaced. The latest innovations on rotary drills include features for automatic drilling.

AN-FO and slurries are still the predominant explosives used in open-pits. The two explosives are compared. The production levels of shovels are compared with explosive consumption.

Beasley, R. P.

Erosion and Sediment Pollution Control.
Iowa State University Press, Ames (1972).

This book treats the movement of soil by nature's forces. The effects of man's disturbance of the environment is discussed.

Movement of soil by wind and water is described. A semi-empirical soil-loss prediction equation is developed. The control and diversion of excess water to prevent erosion by such means as spillways, channels, basins, ponds, etc., are discussed and evaluated. The planning of agricultural systems and urban development with respect to erosion and sediment control are presented.

A basic introduction to field surveying and the use of topographic maps and aerial photographs is given.

Berlyand, M. E.

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Sedimentary Characteristics of Dust Storms: I. Sorting of Wind-Eroded Soil Material.
American Journal of Science, 255, No. 1, pp. 12-22 (1957).

> Sorting of soil materials by the wind is an intricate phenomenon. The most distinct feature in the whole sorting process was found to be the peak diameter of the saltating grains. Fractions larger than the peak diameter tend to remain in the wind-eroded fields, and particles smaller than this diameter tend to be deflated and carried far through the atmosphere. Depending on soil class, from 31 to 78 percent of particles smaller than 0.1 mm in diameter contained in the wind-transported soil fraction are deflated by a single windstorm. Silt generally is more readily deflated than sand or clay. Wind erosion has caused little change in texture of loess soils but has tended to remove the fine constituents from the coarser-textured soils, leaving the sand behind. This sorting process if continued even for a day or two adds considerably to the general sandiness of the affected areas and to consequent irreparable depletion of soil productivity.

Chepil, W. S., and Woodruff, N. P.

Sedimentary Characteristics of Dust Storms: II. Visibility and Dust Concentration.
American Journal of Science, 255, No. 2, pp. 104-114 (1957).

> Analysis of some dust storms in Kansas and Colorado during 1954 and 1955 indicates a relationship between visibility and atmospheric dust concentration when rules of Houghton are followed. Visibility varies inversely as some power of concentration, and concentration varies inversely as a certain power of height. The quantity of soil removed from any region for any storm or period of time can be estimated.

Chepil, W. S.

Sedimentary Characteristics of Dust Storms: III. Composition of Suspended Dust.
American Journal of Science, 255, No. 3, pp. 206-213 (1957).

> Wind-blown dust varied widely in its composition depending on the composition of eroded soil, the year of measurement, and the distance and height of transport. The composition of the dust was like the composition of many samples of loess. The size distribution of dust and of coarser materials transported at any height or deposited anywhere after any single windstorm was characterized by a single peak diameter of the discrete particles and by arms on each side of the peak falling off independently of each other at some constant rate. The peak diameter varied from one graded material to another, depending on the physical nature of the soil, distance and height of transport, and possibly the velocity of the wind.

Cralley, Lewis J.

Identification and Control of Asbestos Exposure.
American Industrial Hygiene Association Journal, 32, No. 2, pp. 82-85 (1971).

> Asbestos can be used safely in modern industrial technology if adequate precautions are taken to prevent excessive and unsuspended exposures. To distinguish between asbestos and other fibers, new techniques must be applied to electron microscopy and diffraction, emission and atomic absorption spectrophotometry, electron microprobe, and neutron activation analytical procedures. Standards and evaluation techniques should be based on airborne fibers and the use of the membrane filter and phase contrast microscopy for sampling and counting. Controls should include procedures for the safe transport of asbestos; exhaust ventilation and personal protection at work sites; the safe disposal of waste dusts; and the prevention of community contamination.

Cummins, David G., Plass, William T., and Gentry, Claude E.

Properties and Plantability of East Kentucky Spoil Banks.
Coal Age, 71, No. 11, pp. 82-85 (1966).

> The spoil bank resulting from strip or open-pit mining is a heterogeneous mass of earth that has physical and chemical properties determined by the rock strata overlying the coal. The material is unique, bearing little

resemblance of the original soil mantle and it may pose difficulties to those attempting revegetation. These difficulties have given rise to our present study of spoils from the eastern Kentucky coal fields. In this study we will identify the chemical and physical characteristics of spoil-bank material and evaluate their influence on plant establishment and growth.

Davis, W. E., and Associates

National Inventory of Sources and Emissions: Cadmium, Nickel, and Asbestos; Section III Asbestos.
National Air Pollution Control Administration, No. CPA 22-69-131, Washington, D.C. (1970).

The flow of asbestos in the United States has been traced and charted for the year 1968. The apparent consumption for the year was 817,363 tons and the domestic production was only 120,690 tons. Imports, mostly from Canada, totaled 737,909 short tons. There was no recovery from scrap.

Emissions to the atmosphere during the year was 6,579 tons. About 85 percent of the emissions were due to mining and milling operations. Estimates of emissions are based for the greatest part on observations made during field trips, and on the limited information provided by mining, milling, and reprocessing companies. Information was not available regarding the magnitude of the emissions or the particulate size.

There were no emission records at any of the locations visited.

Dean, Karl C., Havens, Richard, and Harper, K. T.

Chemical and Vegetative Stabilization of a Nevada Copper Porphyry Mill Tailing.
Bureau of Mines, No. 7261 (1969).

The Bureau of Mines stabilized 10 acres of windblown copper mill tailings at McGill, Nevada, by a combination chemical-vegetative procedure. Legumes, winter wheat, wheatgrasses, and wild rye were seeded, and the area was subsequently sprayed with a resinous adhesive chemical to stabilize the sands until the vegetation could grow. During the year since treatment, the area has been well stabilized against wind erosion. The established vegetation appears to be capable of self-perpetuation and renewal without irrigation. The cost of stabilizing the area was $135.50 per acre.

Dean, Karl C., Havens, Richard, and Valdez, Espiridion G.

USBM Finds Many Routes to Stabilizing Mineral Wastes.
Mining Engineering, 23, No. 12, pp. 61-63 (1971).

In gauging the seriousness of mineral waste problems, cognizance should be taken of the surroundings. Choice of method to alleviate a specific waste problem will depend upon the circumstances of individual waste accumulations. Physical, chemical, vegetative, and combination methods are practical stabilization procedures. Preplanning of waste disposal, often ignored in times past, is now a usual practice.

Denton, George H., Hassel, R. E., and Scott, B. E.

Minimizing In-Transit Windage Losses.
Mining Congress Journal, 58, No. 9, pp. 49-53 (1972).

Low volatile coal utilized by the Youngstown Sheet and Tube Co. is produced by Olga Coal Co. at Coalwood, W.Va.

This coal is used at coke plants at Youngstown, Ohio, and Indiana Harbor, Indiana. Loss of coal in transit has averaged 2,700 lbs. A latex spray has been used to bind the top layer of coal in the railroad hoppers. Loss of coal in transit now averages 600 lbs.

Engineering Equipment Users Association

Recommendations for Handling Asbestos.
Handbook No. 33, London (1969).

Medical hazards in industry have been known from antiquity and new ones are constantly being discovered. It is the duty of management, sometimes legally and always morally, to take every possible step to protect their workmen.

This booklet relates to asbestos, a substance which makes an interesting study in the evolution of occupational hygiene. The ill-effects of inhalation of the dust were known to the Romans: Pliny in the 1st Century A.D. describes the use of respirators by asbestos miners. Nineteen centuries later, in 1931, the Asbestos Regulations were formulated in this country and now, in view of much recent research, they have been revised in order to give protection to whole groups of workers who were not previously recognized as being at risk.

Naturally, the ideal solution is to use a safe substitute, which is the policy being progressively implemented by members of E.E.U.A. However, for cases where substitution is not practicable, and to deal with existing installations, the nature of the hazards and the ways of overcoming them in accordance with the proposed new legislation is described. It is not an unattainable counsel of perfection; precautions along these lines are already in use in many factories all over the country.

Gibbs, Graham W., and Lachance, Maurice

Dust Exposure in the Chrysotile Asbestos Mines and Mills in Quebec.
Archives of Environmental Health, 24, No. 3, pp. 189-197 (1972).

Past and present features of the Quebec chrysotile mining and milling environment and methods used to establish indices of exposure for epidemiological studies are described. Environmental dust concentrations used for calculation of dust exposure indices were derived mainly from systematic midget-impinger samples taken since 1948, using impinger and a variety of other techniques. Though dust levels within the industry fluctuated widely, there was a steady fall from an average of approximately 75 million particles per cubic foot (MPCF) in 1948 to less than 10 MPCF in 1968. Considerable variation in the fiber content of airborne dust in this industry suggests that any safety standard should probably take account of fibrous and nonfibrous components.

Gifford, Franklin A., Jr.

Atmospheric Dispersion.
Nuclear Safety, 1, No. 3, pp. 56-68 (1960).

One of the chief sources of uncertainty in estimating the hazard associated with accidental or planned release to the atmosphere of fission-product activity has been the lack of reliably measured values of atmospheric dispersion coefficients. In the absence of any obvious alternative, Sutton's well-known mathematical dispersion model has been used in many reactor hazards analyses for evaluating effects far beyond the limits for which the model can confidently be expected to be reliable, e.g., distances of the order of 1 km and near adiabatic (neutral) conditions of atmospheric stability. Consequently, the appearance, in several recent papers, of a sizable quantity of new atmospheric dispersion observations is of considerable interest in connection with the meteorology of nuclear safety problems. Furthermore, the calculation of atmospheric dispersion by the method of moving averages, as has been proposed recently, seems to provide an improved means of calculating dispersion, not only because the technique has less restrictive boundary conditions but also because it is well adapted to the interpretation of continuously monitored atmospheric data.

Gifford, Franklin A., Jr.

The Area Within Ground-Level Dosage Isopleths.
Nuclear Safety, 4, No. 2, pp. 91-92, 97 (1962).

The total radioactive dosage to a population has frequently been identified as an important aspect of the potential hazard associated with reactor accidents.

The total population dosage is equal to the product of people times radioactive dosage, summed over the population, with appropriate high- and low-dosage cutoffs taken into account. To expedite computation of this quantity, it is evidently necessary to be able to calculate the area inside ground-level isodose contours, i.e., the intersection between the surface formed by a given air concentration or dosage value and the ground.

Based on ground-level air-concentration isopleths computed by means of the generalized Gaussian dispersion model, calculation of these contours is described.

Gifford, Franklin A., Jr.

Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion.
Nuclear Safety, 2, No. 4, pp. 47-51 (1961).

Estimates of atmospheric dispersion are essential information in the selection of a reactor site and in the evaluation of the hazards of reactor operation. In selecting a site, the dispersion characteristics of the atmosphere at the various sites under consideration are important because most reactors, if not all, generate or induce some atmospheric radioactivity during routine operation and because there is the possibility of accidental release of radioactivity to the atmosphere. Only a few forecasters are familiar with low-level dispersion problems, and consequently it is desirable that simple, easily applied methods of estimating atmospheric dispersion, preferably those employing routine meteorological observations

Gifford, Franklin A., Jr.

Atmospheric Dispersion Calculations Using the Generalized Gaussian Plume Model.
Nuclear Safety, 2, No. 2, pp. 56-59, 67-68 (1960).

A number of formulas for dealing with various practical dispersion problems that arise in reactor hazard analyses are based on the widely used dispersion model formulated by Sutton However, results of recent dispersion experiments have more and more often been presented in terms of the simple Gaussian interpolation formula.

Grossmueck, Gerard

Dust Control in Open Pit Mining and Quarrying.
Air Engineering, 10, July, pp. 21-22, 25 (1968).

More attention is being paid at present to the problems presented by dust in pits and quarries and in ancillary plants. Dust can not only be as much of a nuisance and safety or health hazard as it is underground but it can also become a public liability when the pit or quarry is located in populated areas.

Dust is usually more difficult to control in open pits than underground because clouds or flows of dust-laden air often are not and cannot be confined; huge tonnages of ore or waste are being blasted or broken, handled, and conveyed in wide open spaces; and the influence of uncontrollable atmospheric and climatic conditions may be great.

Also, the mechanical equipment to be used may not have been designed for the particular dust and climatic conditions; or it may not have built-in dust control , so that the mine itself may have to introduce original ideas and designs.

Herod, Sandy

Carson Leads Way in Air Quality Control.
Pit and Quarry, 63, No. 11, pp. 62-68 (1971).

Lime, mined with open pit mining and its subsequent crushing, is a very dusty industry. Methods of dust control in the pit, at the crusher, and on storage piles are described. An environmental conscious staff is necessary to minimize dust.

Holt, P. F., and Young, D. K.

Asbestos Fibers in the Air of Towns.
Atmospheric Environment, 7, No. 5, pp. 481-483 (1973).

Many observers have reported that asbestos bodies are present in the lungs of town dwellers who have had no industrial exposure to asbestos, suggesting that asbestos may be a normal contaminant of the urban atmosphere. The air of several cities -- London, Reading, Rochdale, Bochum, Dussoldorf, Prague, Pitsen, Johannesburgh, and Rcykjavik -- has been sampled using millipore filters. The samples were transferred to carbon film on a grid and they were examined by electron microscopy. Asbestos fibers were found in samples from every town. They were mostly present as single fibrils but some were in agglomerates that contained many fibers.

Horsley, T. L.

Drilling and Blasting at the Cassiar Mine.
The Canadian Mining and Metallurgical Bulletin, 58, No. 6, pp. 625-628 (1965).

This paper deals with the drilling and blasting methods employed at the Cassiar mine, which is located just south of the B.C.-Yukon border. It covers both the "pit" and "peak" mining operations. Specific problems, such as working in frozen ground, are discussed, and the breaking characteristics of the various rock formations are outlined. The paper concludes with a brief mention of the equipment used in the operation, as well as an outline of the breaking costs.

Hutcheson, J. R. M.

Environmental Control in the Asbestos Industry of Quebec.
The Canadian Mining Bulletin, 64, No. 712, pp. 83-89 (1971).

The asbestos mining industry in the Eastern Townships of Quebec has early recognized the undesirable side-effects associated with mineral production, such as air pollution, noise and unsightly waste dumps. In order to efficiently achieve the industry's aim of eliminating or minimizing these objectionable features of mining, all of the asbestos producers in Quebec interchange information, knowledge, and design dealing with the environmental control measures through the Environmental Committee of the Quebec Asbestos Mining Association.

The paper describes what has been done and what is planned for the future in the various problem areas, such as control of dust emitted during the open-pit drilling operation, control of dryer stack emissions, control of the environment in ore, fiber and tailings handling operations, rehabilitation of the countryside covered by waste dumps, and many others.

James, A. L.

Stabilizing Mine Dumps with Vegetation.
Endeavor, 96, pp. 154-157 (1966).

The waste materials from the gold mines of the Witwatersrand in South Africa have accumulated over the years until they have formed large dumps, dangerously liable to erosion by air and water. It was not possible to stabilize these dumps by physical means, and this article describes experiments using vegetation for this purpose. It also describes the methods used to alter the chemical nature of the dumps so that the vegetation would form a permanent establishment.

Laamanen, Arvo, Noro, Leo, and Raunio, V.

Observations on Atmospheric Air Pollution Caused by Asbestos.
Annals of the New York Academy of Sciences, 132, pp. 240-254 (1965).

The mining (quarrying) of asbestos in Finland has been carried out for approximately fifty years. Current production is about 15,000 tons of anthophyllite asbestos per year. In his work on nonoccupational endemic asbestosis, published in 1960, R. Kiviluoto found calcifications of pleura on x-ray examination in approximately

500 people living around the mines. V. Raunio, who at present is continuing the study of the incidence of pleural calcifications in the population around the mines, has mentioned that 1,300 more cases have been found. Kiviluoto, however, estimates that about ten per cent of the population living around the mines might have pleural plaques. At the request of V. Raunio and the Finnish Asbestos Company, Suomen Mineraali, the Institute of Occupational Health has performed some air pollution studies around the mines, to investigate the presence of asbestos in the air. Some preliminary observations have been made.

Lang, L. C., and Favreau, R. F.

A Modern Approach to Open-Pit Blast Design and Analysis.
The Canadian Mining and Metallurgical Bulletin, 65, No. 722, pp. 37-45 (1972).

In modern blasting technology blasts are designed and analyzed on an energy-mass-time relationship. The energy of the explosive is derived by computer analysis and the work potential of the available energy is expressed in numerical values. The mass involved in the blast is determined by the geometry of the blast and by the rock density. Time is also a relevant parameter, because time is required to complete the three basic stages of the breakage process.

For successful application of the blasting parameters, the basic mechanism of the breakage process must be understood.

Lewis, Gordon V.

Foam Drilling-Settling the Dust.
Canadian Mining Journal, 94, No. 9, pp. 42, 48 (1973).

Wet drilling underground has limitations. Foam drilling is an approach to overcome these limitations. Laboratory tests were conducted using foam drilling. Results of the tests are presented and economics of foams discussed.

Li, Ta M.

Dramatic Modernization Program Improves Overall Production at Jeffrey Mine.
Engineering and Mining Journal, 174, No. 10, pp. 78-82 (1973).

> To remain competitive in the world market in the face of rapidly rising mining and processing costs, technical innovation, and larger trucks are necessary. Operations techniques, use, and economics of larger equipment are discussed. History of the Jeffrey mine and future plans are summarized.

Ludeke, K. L.

Soil Properties of Materials in Copper Mine Tailing Dikes.
Mining Congress Journal, 59, No. 8, pp. 30-37 (1973).

> Environmental pollution is a major problem currently facing people everywhere. Federal and state agencies have both enacted legislation and are considering added laws for more effective pollution control.
>
> Present interest in pollution control has directed attention to the accumulation of mine, mill, and smelter wastes that present potential air, water, and environmental pollution hazards. Pollution hazards associated with copper milling may possibly be reduced or eliminated by effective stabilization and revegetation of tailing disposal berms. Pima Mining Co., as an example, has sought to achieve effective control of pollution resulting from its mining and milling operations. In this connection, the company has adopted the foresighted policy of improving the environment, from both a physical and public point of view, and has made financial resources available for the study reported on here. The primary objectives were to (a) make tailing disposal berms esthetically acceptable, (b) facilitate revegetation of such berms, (c) study the problems of soil structure and the chemical composition of the soil materials in mining wastes that may affect revegetation, and (d) eliminate possible environmental pollution problems.

Ludeke, Kenneth L.

Vegetative Stabilization of Tailings Disposal Berms.
Mining Congress Journal, 59, No. 1, pp. 32-39 (1973).

> The objectives of maintaining the natural desert beauty and of minimizing erosion and wind blown dust are being successfully achieved in stabilization program of Pima Mining Co.
>
> Vegetative stabilization has been successful due to proper planning and follow-up. Techniques of stabilization are discussed. A list of trees, shrubs, and grasses which have been successfully used is given. Costs are discussed.

Lumley, K. P. S., Harries, P. G., and O'Kelly, F. J.

Buildings Insulated with Sprayed Asbestos: A Potential Hazard.
Annals of Occupational Hygiene, 14, pp. 255-257 (1971).

> In a survey of storehouses insulated with sprayed crocidolite and amosite asbestos the insulation was found to be damaged because it was unprotected. Dust sampling tests showed that the occupants of these storehouses could be exposed to harmful levels of asbestos dust if the insulation or fallen asbestos debris was disturbed. It is suggested that this hazard may be controlled by sealing the insulation and providing means of protecting the sealed insulation against damage.

Mangold, C. A., Beckett, R. R., and Bessmer, D. J.

Asbestos Exposure and Control at Puget Sound Naval Shipyard.
Puget Sound Naval Shipyard, Industrial Hygiene Division, Bremerton, Washington, (1970).

> A two and one-half year comparison of chest x-ray findings in the total work force of Puget Sound Naval Shipyard shows that 21% of the Pipe Coverers and Insulators handling asbestos have pulmonary abnormalities compared to 3.5% of the Boilermakers who have some exposure to asbestos and silica, and less than 1% of the Clerical workers with no known exposure to industrial dusts. Pulmonary abnormalities have remained high although evaluation of the asbestos dust exposure of Pipe Coverers and Insulators shows their time weighted exposures are below the current Threshold Limit Value of 5 million particles per cubic foot of air. The

Threshold Limit Value may be too high and intermittent peak exposures may play a greater role than suspected. A number of engineering control methods and changes in work practices are suggested to reduce asbestos exposure.

Minnick, L. John

Control of Particulate Emissions from Lime Plants -- A Survey. Journal of the Air Pollution Control Association, 21, No. 4, pp. 195-200 (1971).

This paper describes the achievements of the lime industry in developing methods of handling and controlling the various finely divided products which they produce. An extensive survey provides useful data on the availability and performance of many of the control devices that are currently in use, and an analysis is made of the operating efficiencies and costs of this equipment. The environmental control programs which are currently underway in this industry are described and an evaluation is made of these programs. The ultimate goals that are believed to be attainable are presented from the standpoint of emission control from individual processes as well as from operating plant complexes. While the paper deals primarily with practical operating and engineering aspects of the subject, some information is also included on methods of tests and the monitoring systems that are in use.

Morrison, Joseph N., Jr.

Controlling Dust Emissions at Belt Conveyor Transfer Points. Transactions of the Society of Mining Engineers, 250, No. 1, pp. 47-53 (1971).

A comprehensive solution is offered to the problem of dust emissions at belt conveyor transfer points. Details of enclosure design are discussed and a straightforward procedure for calculating required dust control exhaust volume is presented. Many design variables are taken into account which heretofore have been commonly ignored or inadequately considered. These include belt widths, belt speeds, enclosure openings, material flow rate, material bulk densities, material lump sizes, height of material fall, material temperature, and ambient air temperature. All of these questions are handled by means of a "fill-in-the-blanks" type of calculation form, permitting quick, reliable solutions by relative "non-experts".

Newhouse, Muriel L.

Asbestos in the Work Place and the Community.
Annals of Occupational Hygiene, 16, pp. 97-107 (1973).

The fibrogenic properties of asbestos dust were detected early, later knowledge accumulated about the carcinogenic properties of the mineral and a hazard of bronchial carcinoma and mesothelial tumours was recognized.

Mortality studies have measured the effect of exposure on working populations. Recent analysis of data from a cohort of asbestos factory workers shows that even with low to moderate exposure there is excess mortality from cancer of the lung and pleura and other cancers, after more than 25 years' observation. The mesothelioma rate increases both with severity and length of exposure. Occurrence of these and other tumours appears to be dose-related. The markers of a community effect of asbestos dust in the environment are the occurrence of mesothelial tumours in neighbourhoods of a source of asbestos dust, and the presence of asbestos bodies or calcified asbestos pleural plaques in the general population. Conditions giving rise to neighbourhood mesothelial tumours may not now occur, but the importance of adequate control in all countries where asbestos is mined or manufactured is stressed.

Nicholson, William, J., and Rohl, Arthur N.

Asbestos Air Pollution in New York City.
Proceedings of the Second International Clean Air Congress.
pp. 136-139 (1970).

Sampling for asbestos in the ambient air of New York City was performed. Preliminary results show concentrations ranging from 11 to 60 x 10^{-9} grams/m^3. In the vicinity of the spraying of fireproofing containing asbestos materials, concentrations of 20 x 10^{-9} g/m^2 were found upwind and concentrations of 45 to 180 x 10^{-9} g/m^3 were found downwind.

Noro, Leo

Occupational and Non-Occupational Asbestosis in Finland.
American Industrial Hygiene Association Journal, 29, No. 3
pp. 195-201 (1968).

The history of asbestos and asbestosis in Finland is presented. In addition to the occupational-related incidences of asbestosis, residents especially farmers in regions near asbestos deposits show an increased incidence of asbestos bodies in lung studies.

Pasquill, F.

The Estimation of the Dispersion of Windborne Material.
The Meteorological Magazine, 90, No. 1063, pp. 33-49 (1961).

The theoretical estimation of the concentrations arising from sources of gaseous or finely divided particulate material has for long been based on treatments of atmospheric diffusion developed by Sir Graham Sutton. These formulae are reliable for specifying the average distribution, over a few minutes on level unobstructed terrain, with a steady wind direction and neutral conditions of atmospheric stability. Extension to other circumstances has depended on empirical and often speculative adjustments of the diffusion parameters.

During the last few years, investigations have shown that a fairly rational allowance can now be made for the effects of much of the wide variation in atmospheric turbulence which occurs in reality. This progress includes some extension to longer distances of travel.

The purpose of this article is to review the recent background of theoretical and experimental results, and to give details of the proposed system of calculating the distribution of concentration downwind of a source. These details are set out in two appendices, the first giving complete instructions for carrying out the calculations, the second presenting an example.

Popa, Bazil, and Iancau, Vasile

The Probability of Certain Concentrations in the Dispersion of Solid Dust Particles in Industrial Regions.
Staub-Reinhaltung, der Luft, 33, No. 1, pp. 20-24 (1973).

The measurement of particulate components in the air is necessary to the health of a community. The prediction of concentrations of particulates is necessary for the planning of controls on present sources and the introduction of new industry, i.e., new sources in the region.

The influence of the wind is of prime importance, not only its speed but its direction, is discussed. Wind is a random variable and mathematical presentation using statistics are given. Various distribution curves (exponential, logistic, Fisher-Tippett type II (Freehent) and type I (Gumbel), Cauchy, normal Laplace-Gauss) are compared. The town of Cluj, Romania, is used as an example.

Porter, D. D.

Use of Rock Fragmentation to Evaluate Explosives for Blasting.
Mining Congress Journal, January, pp. 41-43 (1974).

A quantitative study of the performance of explosives under model shooting conditions has led to derivation of a mathematical relationship between fragmentation effectiveness of explosives and such measurable parameters as detonation velocity, explosive energy, density, and rock sonic velocity. Through this relationship, one is accounting for parameters long known to affect the performance of explosives.

Significantly, the potential now exists for dealing with these parameters on the basis of their interrelationship with field loading conditions and rock properties. Initial field tests to develop practical applications of this relationship as a predictive tool have revealed several problematic considerations, but they also have demonstrated the potential for developing a useful tool for evaluating the fragmentation effectiveness of different explosives on a theoretical basis as an aid to selecting specific formulations for individual jobs.

Powlesland, J. W.

Air Curtains.
Canadian Mining Journal, 92, No. 10, pp. 84-85 (1971).

Airflow regulators, thermal barriers, dust, and fume control are all accomplished with jet streams without the use of hoods and ducts.

Rajhans, Gyan S.

Fibrous Dust - Its Measurements and Control.
The Canadian Mining and Metallurgical Bulletin, 63, No. 8, pp. 900-910 (1970).

The strategy of fibrous dust sampling is discussed, various sampling methods are critically reviewed and their application to coal dust is demonstrated. Fiber counting is described in detail. An attempt is made to explain the basis of determining the threshold limit value of asbestos and other dusts.

The paper also discusses such dust control methods as enclosure of the process, effective local exhaust ventilation, segregation, substitution, wet processing, and continuous monitoring of the return air for recirculation.

Randveer, Elmar

Tangential Blowers in Dust Control.
Canadian Mining Journal, 92, No. 10, p. 29 (1972).

Dumping of ore into the crusher pocket is a major source of dust. Tangential blowers were installed at Ecstall Mining, Ltd., to solve this problem. The air curtain system together with the dust collection equipment is described. Tests on the actual installation show an efficiency of 85 to 90% suppression of dust.

Reitze, William B., Nicholson, William J., Holaday, Duncan A., and Selikoff, Irving J.

Application of Sprayed Inorganic Fiber Containing Asbestos: Occupation Health Hazards.
American Industrial Hygiene Association Journal, 33, No. 3, pp. 178-191 (1972).

Over 40,000 tons of inorganic fibrous insulation containing asbestos were used in 1970 by the construction industry as a fireproofing material in the erection of multistoried buildings. The application of this material by a spraying technique produces serious contamination of the working environment. Asbestos fiber concentrations may range from 30 f/cc to more than 100 f/cc. Some early observations of the exposures and health of the workmen in this comparatively new occupation are given with photographs of the working areas. Nearby workers may be indirectly exposed. Such concentrations were found to be 70 f/cc ten feet from the spraying and 46 f/cc seventy-five feet away. Control measures are discussed.

Reitze, William B., Holaday, D. A., Romer, Harold, and Fenner, E. M.

Control of Asbestos Fiber Emissions from Industrial and Commercial Sources.
Proceedings of the Second International Clean Air Congress, pp. 100-103 (1970).

> There are five major sources from which asbestos fiber enters the air -- (1) mining, (2) milling (3) manufacturing, (4) certain segments of the construction industry, and (5) naturally occurring sources. The first four are created by modern man's technology and the last by normally occurring changes in our environment.
>
> The operations of each source with controls that are now in use are listed.

Roach, S. A.

Hygiene Standards for Asbestos.
Annals of Occupational Hygiene, 13, pp. 7-15 (1970).

> Criteria for establishing the standards for asbestos is discussed. The dose response of individuals and population is presented in general and the response to chrysotile asbestos exposure is plotted. The accumulated exposure of 100 fibers years/cm^3 is the threshold to limit early clinical signs to 1% of the population. This exposure-response, as it is related to the present exposure limits, is discussed.

Scharf, Allan

Preliminary Report on Reduction of Airborne Dust Produced by Pneumatic Jackhammers.
American Industrial Hygiene Association Journal, 28, No. 5, pp. 479-481 (1967).

> In preliminary findings, the use of a new continuous flow water attachment for jackhammers has shown encouraging results in its dust suppression capabilities. This attachment reduces airborne sandstone dust concentrations rather than precipitate the dust once airborne. Using Student's "t" test the difference between the means for wet conditions were compared with dry jackhammering. These differences were highly significant in 8 trenches, significant in 2 trenches, and no significant in 1 trench. It is concluded that further development of the water attachment is in order.

Scharf, Allan

Control of Airborne Dust Produced by Pneumatic Jackpicks: Report Number II.
American Industrial Hygiene Association Journal, 30, No. 5, pp. 519-522 (1969).

> This report concerns analyses of data collected from 48 excavation sites at which a cone-shaped continuous flow water attachment for jackpicks was in use. The attachment reduces airborne sandstone dust concentrations rather than precipitate the dust once airborne. This testing of the attachment supported original findings concerning its favorable dust suppression capabilities. The superiority of placing the cone near the pickpoint at commencement of picking over placing the cone a remote distance from the pick point is demonstrated. No correlation between dust concentrations and trench depth was found during dry picking. Under wet picking conditions, a correlation was found.

Scharf, Allan

Control of Airborne Dust Produced by Pneumatic Jackpicks with Water Attachments: Report III.
American Industrial Hygiene Association Journal, 33, No. 1, pp. 48-53 (1972).

> The dust suppression capabilities of a cone-shaped water attachment for pneumatic jackpicks (Mark 3) was compared with similar capabilities of a coil-shaped attachment (Mark 4). The Mark 4 design, in the field, significantly reduced hazardous sandstone dust concentrations when compared with the Mark 3 (Student's "t" test, $P < 0.02$). The Mark 4 used significantly less water (Student's "t" test, $P < 0.01$). There is a tendency for the percentage of decrease in dust to be associated with the percentage of the water reaching the impact point of the jackpick steel.

Scharf, Allan

Control of Airborne Dust Produced by Pneumatic Jackpicks: Report IV. Calibration of Water Attachments.
American Industrial Hygiene Association Journal, 34, No. 4, pp. 171-175 (1973).

> The rates of water flow were measured from the impact point of a jackpick steel fitted with a cone-shaped Mark 3 and a coil-shaped Mark 4 water attachment. The

Mark 4 more consistently distributed water to the pick point with the coil in an up and down position than the Mark 3. In addition, the percent of water reaching the impact point of the jackpick steel (at different set rates of water flow, from different water attachments) could be expected to demonstrate the optimum rate of flow for each attachment tested.

Schutz, L. A., Bank, Walter, and Weems, George

Airborne Asbestos Fiber Concentrations in Asbestos Mines and Mills in the United States.
Bureau of Mines Health and Safety Program, No. 72, Washington, D. C. (1973).

Personnel of the Bureau of Mines have conducted investigations in the principal asbestos mines and mills in the United States, to determine the concentration of airborne asbestos fibers in the workplace, and to establish the exposure of workers to such fibers. The surveys were conducted using the sampling and evaluation method recommended by the National Institute for Occupational Safety and Health. The method consists of collecting the airborne sample on filters and, after appropriate sample preparation, counting the fibers utilizing phase contrast microscopy. The results of the investigation show that fiber concentrations are low in the asbestos mines but high in the asbestos mills, ranging well above 5 fibers/ml of air based on a count of fibers greater than 5 μm in length.

Selikoff, I. J., Hammond, E. C., and Heimann, H.

Critical Evaluation of Disease Hazards Associated with Community Asbestos Air Pollution.
Proceedings of the Second International Clean Air Congress, pp. 165-171 (1970).

The results of 3,000 consecutive autopsies in New York City is correlated with asbestos bodies. The results of sampling the ambient air of New York City show an asbestos air level of 11 to 60 x 10^{-9} g/m^3. Types of exposure as well as sources and control methods are discussed.

Shore, D. V.

Current Blasting Trends in Open-Pit Mining and Quarrying.
Australian Mining, 64, No. 10, pp. 20-21, 25 (1972).

> The dominant trend in open-pit mining and quarrying in Australia is the increased outputs from individual locations. This article outlines the importance of new explosives technology in the trend and the kinds of blasting found suitable for the various locations.

Simecek, Jaroslar

Dust Investigations in an Asbestos-Processing Plant and Its Surroundings.
Staub-Reinhalt der Luft, 31, No. 12, pp. 26-31 (1971).

> In an asbestos processing plant dust concentrations were determined at working places and also in the plant surroundings. The individual working places can be assessed on the basis of results obtained by measurements carried out from 1965 to 1969. The measurements effected outside the plant buildings have shown that the maximum value of 0.15 mg/m^3 was exceeded in the summer months in 20% of the cases, and in the winter months in 50% of the cases. The asbestos particles present in samples are detected under the electron microscope. The particle size distribution and concentration (1.7 particles/cm^3), and also the asbestos content (<1 weight %), were determined.

Skidmore, E. L.

Assessing Wind Erosion Forces: Direction and Relative Magnitudes.
Soil Science Society of America Proceedings, 29, No. 5, pp. 587-590 (1965).

> Wind erosion force vectors were computed from data of frequency of occurrence of directions by windspeed groups based on wind erosion being proportional to windspeed cubed times the duration of the wind. The vectors were obtained by evaluating $\Sigma \bar{U}_1^3 f_1$ for each of the 16 principal directions where $\bar{U}_1^3$ is the cubed mean windspeed within the ith speed group and f_1 is percentage of total observations that occur in the speed group and direction under consideration.
>
> The wind erosion force vectors were used to compute monthly magnitudes of the total wind erosion forces and direction where the ratio of the wind erosion forces

parallel and perpendicular to that direction is a maximum. The computed direction indicates proper orientation of a wind barrier for maximum barrier protection. The magnitude of the ratio gives the preponderance of wind erosion forces in the direction of maximum wind erosion forces. The magnitude of the total wind erosion forces indicates the potential need for protection against the erosion forces.

Skidmore, E. L., Fisher, P. S., and Woodruff, N. P.

Wind Erosion Equation: Computer Solution and Application.
Soil Science Society of America Proceedings, 34, No. 6,
pp. 931-935 (1970).

A wind-erosion equation was programmed for computer solution. The relationships among variables are evaluated by the computer and the general functional relationship between soil loss and independent variables, $E = f(I', C', K', L', V)$, is solved stepwise to give potential average annual soil loss, E, in tons per acre per annum for specified conditions of erodibility, I'; roughness, K'; climatic factor, C'; equivalent field length, L'; and equivalent vegetative cover, V. The computer also can solve the equation to determine field conditions necessary to reduce potential erosion to a tolerable amount and can compare the effectiveness of various combinations of erosion-control treatments.

Sullivan, Ralph J., and Athanassiadis, Yonis C.

Air Pollution Aspects of Asbestos.
National Air Pollution Control Administration, No. PH-22-68-25,
Washington, D.C. (1969).

Inhalation of asbestos may cause asbestosis, pleural or peritoneal mesothelioma, or lung cancer. Mesothelioma is a rare form of cancer which occurs frequently in asbestos workers. All three of these diseases are fatal once they become established. The dose necessary to produce asbestosis has been estimated to be 50 to 60 million particles per cubic foot-years. No information is available on the dose necessary to induce cancer. Random autopsies of lungs have shown "asbestos bodies" in the lungs of one-fourth to one-half of samples from urban populations. Thus, the apparent air pollution by asbestos reaches a large number of people.

Animals have been shown to develop asbestosis and cancer after exposure to asbestos.

No information has been found on the effects of asbestos air pollution on plants or materials.

The likely sources of asbestos air pollution are uses of the asbestos products in the construction industry and asbestos mines and factories. Observations in Finland and Russia indicate that asbestos does pollute air near mines and factories. However, no measurements were reported of the concentration of asbestos near likely sources in the United States. A concentration in urban air of 600 to 6,000 particles per cubic meter has been estimated.

Bag filters have been used in factories to control asbestos emissions; the cost of this type of control in a British factory was approximately 27.5 percent of the total capital cost and about 7 percent of the operating cost. No information has been found on the costs of damage resulting from asbestos air pollution.

No satisfactory analytical method is available to determine asbestos in the atmosphere.

Turner, D. Bruce

Workbook of Atmospheric Dispersion Estimates.
National Air Pollution Control Administration, Cincinnati (1970).

This workbook presents methods of practical application of the binormal continuous plume dispersion model to estimate concentrations of air pollutants. Estimates of dispersion are those of Pasquill as restated by Gifford. Emphasis is on the estimation of concentrations from continuous sources for sampling times up to one hour. Some of the topics discussed are determination of effective height of emission, extension of concentration estimates to longer sampling intervals, inversion break-up fumigation concentrations, and concentrations from area, line, and multiple sources. Twenty-six example problems and their solutions are given. Some graphical aids to computation are included.

Wood, C. H., and Roach, S. A.

Dust in Card Rooms: A Continuing Problem in the Cotton-Spinning Industry.
British Journal of Industrial Medicine, 21, No. 3, pp. 180-186 (1964).

The results are given of environmental and clinical investigations in four card rooms where one of the latest systems of exhaust ventilation to control dust has been installed. The concentration of airborne coarse dust particles, larger than 2 mm, was reduced by between 80% and 90% around the carding engines. The card rooms consequently looked less dusty. However, the concentrations of medium and fine sized dust particles were not always reduced and were actually increased in some places. In one mill, when the new control system had been running for three years, there was found to be no reduction in the prevalence of non-specific chest symptoms, and there was an increase in the number of those with chest tightness on Mondays, a symptom characteristic of byssinosis. Evidence is given of a similar failure to reduce the dust sufficiently in three other mills where the same exhaust system is installed.

There is an urgent need to extend the limited investigations reported here to a larger number of mills. Meanwhile there is a continuing morbidity and mortality from byssinosis. Until work in card rooms has been made safe and proved to be so, it is necessary to have regular measurement of dust conditions and for the workers to have periodical medical examinations to enable managements to be advised about the hazards in their mills and advice to be given to the individuals affected by the dust.

Woodruff, N. P., and Siddoway, F. H.

A Wind Erosion Equation.
Soil Science Society of America Proceedings, 29, No. 5, pp. 602-608 (1965).

The amount of erosion, E, expressed in tons per acre per annum, that will occur from a given agricultural field can be expressed in terms of equivalent variables as: $E = f(I', K', C', L', V)$ where I' is a soil erodibility index, K' is a soil ridge roughness factor, C' is a climatic factor, L' is field length along the prevailing wind erosion direction, and V is equivalent quantity of vegetative cover. The 5 equivalent variables are obtained by grouping some and converting others of the 11 primary variables now known to govern wind erodibility. Relations among variables are extremely complex. Charts and tables have been developed to permit graphical solutions of the equation. The equation is designed to serve the twofold purpose of providing a tool to (i) determine the potential erosion from a particular field, and (ii) determine what field conditions of soil cloddiness, roughness, vegetative cover, sheltering by barriers, or width and orientation of field are necessary to reduce potential erosion to a tolerable amount. Examples of these applications of the equation are presented. Weaknesses in the equation and areas needing further research are discussed.

Appendix B

ABSTRACTS OF CURRENT, RELATED RESEARCH PROGRAMS UNDER SPONSORSHIP OF THE DEPARTMENT OF THE INTERIOR, BUREAU OF MINES, WASHINGTON, D.C.

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Troy Achenback
"A Feasibility Study on the Use of Foam to Reduce Respirable Coal Dust on a Joy 10 CM Continuous Miner"
Agency No. 03388
Peabody Coal Company, Pawnee, Illinois

Abstract

The contractor shall conduct a program to ascertain the effectiveness of a foam system in reducing the amount of respirable coal dust generated during an actual mining operation. Nozzles will be mounted on a Joy 10 CM continuous miner and tests will be conducted in Peabody's No. 10 mine, Pawnee, Illinois. Peabody Coal Company will test underground for 40 shifts, preferably at a rate of two shifts per day, alternating daily between foam and water so that the sampling results of 20 shifts with foam can be compared with an equivalent 20 shifts of water.

L. Cheng
"Dust Control at and Outby the Face"
Agency No. 03159
Pittsburgh Mining and Safety Research Center
4800 Forbes Avenue, Pittsburgh, Pa. 15213

Abstract

A theoretical model for the capture of airborne dust was developed and verified in the laboratory. The theory can be used to select a spray nozzle which gives spray drops having a higher collection efficiency of airborne dust at a specific spray-nozzle location in a mine for the water flow rate, line pressure, and geometry at that location. In practice, of course, the water spray drops can also impact and moisten the surface of the coal and prevent dust from becoming airborne. The development of a theoretical impaction model is being studied, and combination of the impaction and airborne models will then be attempted.

In the interim, the usefulness of the above airborne theory for improved dust suppression at the front end of a continuous mining machine was tested underground. In one test series, "good" sprays gave one-third less dust than other water sprays and also used one-third less water. In a second test series, dust suppression was about equal with all spray nozzles, although the good sprays still used about one-third less water.

J. B. Cheung
"Surface Hard Rock Excavator to Reduce Environmental Impact of Drilling and Blasting"
Agency No. 9500 - 1.2
Twin Cities Mining Research Center, P.O. Box 1660,
Twin Cities, Minn. 55111

Abstract

Develop and test a new surface hard rock excavation system as an alternative to the conventional quarrying practice. Field testing of the thermal-mechanical breaking method both for in-situ breaking and secondary crushing of hard rocks will be carried out. The effect of geology and rock property variations on the method will be determined. The environmental impact and economic assessments of both the thermal and conventional (drilling and blasting) methods will be made to establish the relative advantages and cost effectiveness of the thermal excavator. The results will provide engineering data for the design of a thermal excavator system for full-scale experimental demonstrations.

John B. Cheung
"Thermal Fragmentation Methods for In-Situ and Secondary Crushing of Hard Rocks"
Agency No. 9500 - 1.9
Twin Cities Mining Research Center, P.O. Box 1660,
Twin Cities, Minn. 55111

Abstract

This project will evaluate the process efficiency of different surface heating methods to achieve thermal fragmentation and size reduction of hard rocks. A mechanically assisted process of fracture completion and fragment removal will be examined and the process efficiency of a thermo-mechanical combination method of rock fragmentation will be evaluated during FY 1972. An experimental study will be made to evaluate the thermal shock concept for size reduction of rocks. The energy coupling efficiency for surface heating and fragmentation of hard rocks will be examined.

W. G. Courtney
"Dust Control Technology"
Agency No. 03406
Pittsburgh Mining and Safety Research Center,
  4800 Forbes Avenue, Pittsburgh, Pa. 15213

Abstract

The objective is to obtain background information for improving the Bureau's dust enforcement program for the non-coal mining industry. Exploratory field information on dust concentrations using an assortment of dust samplers will be obtained. In addition, the time variation in dust levels and the validity of the present Bureau sampling system will be investigated.

Walter W. Fowkes
"Reclamation of Spoil Banks"
Agency No. 8751-4140
Grand Forks Energy Research Laboratory, Box 8213,
  University Station, Grand Forks, N.D. 58201

Abstract

A survey will be conducted of current efforts on spoil bank reclamation from strip mining by major mining companies in areas of North Dakota, eastern Montana, and eastern Wyoming. Based on this information, examine further the soil characteristics and types of indigenous vegetation so as to identify opportune sites for field studies. At selected sites, incorporate combustion products and/or coal into the soil after a minimum of topographic preparation; then, seed or plant and observe along with control plots.

Growth response and self-sustaining character of the revegetation efforts will be examined in relation to age of spoils, micronutrient availability, and changes in physical properties of the soil effected by various amendments.

J. N. Frank
"Augmentation of Mechanical Coal Miner with Fluid Jets"
Agency No. 8931 - 1.2
Twin Cities Mining Research Center, P.O. Box 1660,
  Twin Cities, Minn. 55111

Abstract

Fluid jets will be installed on a mechanical coal miner to determine if the amount of respirable dust generated by a mining machine can be reduced or suppressed and if the coal extraction rate can be improved. The testing program will utilize the microminer, built by Battelle Columbus Laboratories under a H&S contract, and a fluid jet system capable of pressures up to 30,000 psi. Measurements will be made of the amount of respirable dust generated and the extraction rate during coal cutting tests in the Center's large-scale testing laboratory. Field tests at an opencast coal mine will be started late in FY 1974 and continued in FY 1975 to assess this method under field operating conditions.

R. A. Friedel
"Air Pollution from Mining and Processing (NASA)"
Project Nos. 5556 and 5557
Pittsburgh Energy Research Center, 4800 Forbes Avenue,
  Pittsburgh, Pa. 15213

Abstract

Photographic and instrumentation methods are used to ascertain ecological damage -- destruction of foliage, strip mining scars, pollution of rivers and lakes, air pollution from mineral processing, etc.

D. W. Gillmore
"Reclamation of Coal Mining Waste Areas"
Agency No. 4-1161
Morgantown Energy Research Center, Morgantown, W.V. 26505

Abstract

Purpose: To demonstrate the physical and chemical benefits of using power-plant fly ash in the reclamation and revegetation of surface mine spoil and coal mine disposal areas.

Consulting and some machine services will be provided on a variety of cooperative projects, particularly those on

refuse bank reclamation and in reclaiming anthracite culm banks.

Newer fly ash application and mixing techniques, such as hydraulic injection for high walls and out slopes, rock crushing and pulvimixing will be investigated.

Ralph Hiltz
"Underground Application of Foam for Suppression of Respirable Dust"
Agency No. 03349
MSA Research Corporation, Evans City, Pa.

Abstract

Dust suppression is still a problem in some continuous mining applications, but especially so in low coal auger mining and long wall systems. Previous tests have offered sufficient encouragement to warrant further investigation into the suppression of respirable dust at the face by means of high expansion surfactant foam. This contract will test foam application on two continuous miners in high coal in two different coal seams, one of which contains rock partings. a low coal auger miner, and a long wall shearer section. Also, the effect of the surfactant foam on the dust generated by secondary handling will be evaluated simultaneously.

Dennis H. Irby
"Respirable Dust Abatement"
Agency No. 4088 - 2.1
Twin Cities Mining Research Center, P.O. Box 1660,
Twin Cities, Minn. 55111

Abstract

This project deals with two of the health hazards in metal and nonmetal mining associated with rock drills, respirable dust and drilling noise. The objective is to devise means of measuring respirable dust and noise generated by rock drills and to determine the relationship of rock and drill parameters to these hazards. Significant parameters that would minimize these hazards will be sought.

C. D. Kealy
"Design Theory - Coal Waste Dumps"
Agency No. 8783-I
Spokane Mining Research Center, N. 1430 Washington St.,
  Spokane, Wash. 99201

Abstract

Purpose: Develop new design criteria and theory for surface-waste disposal (coal and metal-nonmetal) including investigations into disposition of tailings and coal sludge, slope stability, fill stabilization, air/water pollution, and land reclamation. Both static and dynamic analysis will be pursued as well as nonsaturated flow. Define, analyze, and develop solutions for disposal of waste products from all types of mining operations.

J. M. Link
"Feasibility of Hydraulic Transportation in Underground Coal Mines"
Agency No. 03348
Colorado School of Mines Research Institute, P.O. Box 112,
  Golden, Colorado 80401

Abstract

The purpose of this research is to design a total mine hydraulic pipeline system that is fail-safe and design each of the hydraulic pipeline subsystems for conveying run-of-mine coal (including normal refuse content) from continuous mining machines to a surface loading point or preparation plant. It is to determine the economic potential and calculate capital, operating, and depreciation cost estimates for this system and each subsystem. The subsystems are face haulage, multiple feed secondary haulage, and vertical hoisting. In addition, costs will be calculated for conventional haulage subsystems such as shuttle car, conveyor belt, rail, and skip hoisting.

F. E. McCall
"Investigate the Effectiveness of Water Stemming as a Means of Suppressing Respirable Dust Resulting from Explosive Fragmentation of Coal"
Agency No. 03160
Pittsburgh Mining and Safety Research Center,
4800 Forbes Avenue, Pittsburgh, Pa. 15213

Abstract

A Bureau study showed that coal mine personnel involved in conventional mining are exposed to about the same amount of respirable dust as similar personnel involved in continuous mining. Dust control techniques therefore must be developed for conventional mining operations.

One source of respirable dust during conventional mining is the blasting operation. The objective of this program was to investigate the effectiveness of water and Trabant gel compared to dry clay as stemming materials for controlling the formation of respirable dust.

The investigation shows (1) no significant difference between the amount of airborne respirable dust generated using water or gel as the stemming material, (2) both the gel and water give about 70 percent less respirable dust than was obtained with dry clay as a stemming material, and (3) reentry time with gel or water was immediate while smoke lingered for several minutes with dry clay. Most of the airborne dry-clay-stemmed respirable dust was dry-clay dust. Negligible amounts of CO and NO_2 were observed with all stemming materials.

S. J. Rodgers
"Experience Survey of Dust Control Methods in Noncoal Mines"
Agency No. 03281
MSA Research Corporation, Evans City, Pa.

Abstract

The contractor will conduct a detailed survey of past and present engineering methods used to control respirable dust in the noncoal mining industries and also will identify dust control problem areas. Dust control methods in asbestos, bentonite, copper, talc, uranium, lead, iron, gold, molybdenum and crushed-stone mines, quarries, and ore processing mills will be included. The program will include a search of existing literature and personal contacts with the major mining companies and companies specializing in dust control equipment. The survey will include established procedures that

are in widespread use throughout the mining industry but also will include any unique methods which may be found. The findings will be assembled in a systematic manner as a final report which is to include a manual of dust control techniques which can be used by mine operators.

R. L. Soderberg
"Design Criteria for Mine and Mill Waste Disposal Systems"
Agency No. 8783 - 6.1
Spokane Mining Research Center, N. 1430 Washington St.,
  Spokane, Wash. 99201

Abstract

Purpose: Study, define, analyze, and develop solutions for disposing of waste products from the mining of large, low-grade ore deposits.

Problems with surface disposal of tailings will be material segregation, water movement, stabilization, effect of topographic conditions, and effect of surface or underground water. The mining of large, low-grade ore deposits will only be possible through the handling of large amounts of material, and the resultant large quantities of waste products must be adequately disposed of.

R. F. Stewart
"The Pneumatic Transportation of Coal"
Agency No. 07023
Morgantown Energy Research Center, P.O. Box 880,
  Morgantown, W.V. 26505

Abstract

The objective is to determine the technical and economical feasibility of pneumatically transporting mine-run coal from the working face to the surface.

Horizontal vacuum tests were completed; and empirical equations that correlate minimum air and power requirements with coal throughput rate, pipe diameter, and specific gravity of the coal were derived. The highest haulage rate achieved experimentally was 18 tons per hour of 1-inch coal of 1.4 specific gravity through 370 feet of 6-inch-diameter pipeline. The minimum air rate at pickup was 814 actual cfm and the total pressure drop 7 inches of mercury. Extrapolation of the equations indicates that 155 tons per hour of 4- by 0-inch coal of 1.4 specific gravity can be vacuum transported

through 200 feet of straight 12-inch-diameter pipeline with a pressure drop of 10 inches Hg and a minimum air rate of 5,470 actual cfm or a theoretical horse-power requirement of 154.

Horizontal pressure and vertical pressure tests were completed, and the data are being evaluated. Cost analyses for installation and use of pneumatic transport systems in underground coal mines are being performed.

K. Thirumalai
"Fragmentation and Fusion Cutting of Hard Rocks Using a Combination Thermohydraulic Process"
Agency No. 9500 - 3.1
Twin Cities Mining Research Center, P.O. Box 1660,
Twin Cities, Minn. 55111

Abstract

The purpose of this study is to examine a new concept of continuous hard rock excavation by combining the advantages of the thermal and hydraulic processes of rock disintegration and to conduct laboratory and in-situ tests to examine the potential of the concept for hard rock excavation. During FY 1972, a basic understanding of the combination method of rock disintegration will be developed and its application for hard rock mining will be examined.

R. P. Vinson
"Control of Respirable Dust by Water Infusion"
Agency No. ICIS 03007
Pittsburgh Mining and Safety Research Center,
4800 Forbes Avenue, Pittsburgh, Pa. 15213

Abstract

The objective of this program is to evaluate the dust suppressing ability of water infusion. Closely associated with this is the development of safe and efficient infusion procedures that are applicable to mines and mining methods of the United States. To fulfill these goals, water infusion studies are being conducted in the active sections of mines working different coalbeds. Water flooding experiments have been conducted in both the Pittsburgh and Pocahontas No. 3 coalbeds. Future plans are to experiment with water infusion in the Lower Freeport and Upper Kittanning coalbeds.

H. W. Zeller
"Airborne Dust Control"
Agency No. 8931 - 4.1
Twin Cities Mining Research Center, P.O. Box 1660,
  Twin Cities, Minn. 55111

Abstract

Research on the effects of the use of foam or mist to capture airborne dust generated by a percussive rock drill will be completed during FY 1974.

The main effort in FY 1974 will be the assessment of dust hazards in surface and underground metal and nonmetal mines. The objective of this research is to quantitatively identify dust hazards associated with mining operations with particular emphasis on underground mining. Extensive onsite dust assessments will be performed to identify and classify airborne dust hazards.

The information obtained will be used to identify points of dust generation or liberation where the state-of-the-art dust control technology is not adequate to maintain air quality at the levels specified by law. These results will then be input for the FY 1975-1976 effort to provide industry-wide solutions to metal and nonmetal dust hazards.

Appendix C

POLLUTANT CONCENTRATION FORMULAE FOR THE CLIMATOLOGICAL DISPERSION MODEL

POLLUTANT CONCENTRATION FORMULAE FOR THE CLIMATOLOGICAL DISPERSION MODEL

1. POLLUTANT CONCENTRATION FORMULAS

The pollutant concentration formulas used in the Climatological Dispersion Model are based on the Gaussian plume formula.

The average concentration $\overline{C}_A$ due to area sources at a particular receptor is given by

$$\overline{C}_A = \frac{16}{2\pi} \int_0^{\infty} \left[\sum_{k=1}^{16} q_k(\rho) \sum_{\ell=1}^{6} \sum_{m=1}^{6} \phi(k,\ell,m) S(\rho,z;U_\ell,P_m) \right] d\rho \tag{C1}$$

where

k = index identifying wind direction sector

$q_k(\rho) = \int Q(\rho,\theta)\, d\theta$ for the k sector

$Q(\rho,\theta)$ = emission rate of the area source per unit area and unit time

ρ = distance from the receptor to an infinitesimal area source

θ = angle relative to polar coordinates centered on the receptor

ℓ = index identifying the wind speed class

m = index identifying the class of the Pasquill stability category

$\phi(k,\ell,m)$ = joint frequency function

$S(\rho,z;U_\ell,P_m)$ = dispersion function defined in Equations C3 and C4

z = height of receptor above ground level

U_ℓ = representative wind speed

P_m = Pasquill stability category

For point sources, the average concentration $\overline{C}_p$ due to n point sources is given by

$$\overline{C}_p = \frac{16}{2\pi} \sum_{n=1}^{6} \sum_{\ell=1}^{6} \sum_{m=1}^{6} \frac{\phi(k_n,\ell,m) G_n S(\rho_n, z; U_\ell, P_m)}{\rho_n} \qquad (C2)$$

where

k_n = wind sector appropriate to the n^{th} point source

G_n = emission rate of the n^{th} point source

ρ_n = distance from the receptor to the n^{th} point source

If the receptor is presumed to be at ground level, that is, $z = 0$, then the functional form of $S(\rho,0;U_\ell,P_m)$ will be

$$S(\rho,0;U_\ell,P_m) = \frac{2}{\sqrt{2\pi} U_\ell \sigma_z(\rho)} \exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z(\rho)}\right)^2\right] \exp\left(\frac{-0.692\rho}{U_\ell T_{1/2}}\right) \qquad (C3)$$

if $\sigma_z(\rho) \leq 0.8$ L and

$$S(\rho,0;U_\ell,P_m) = \frac{1}{U_\ell L} \exp\left(\frac{-0.692\rho}{U_\ell T_{1/2}}\right) \qquad (C4)$$

if $\sigma_z(\rho) > 0.8$ L. New terms in Equations C3 and C4 are defined as follows:

$\sigma_z(\rho)$ = vertical dispersion function, i.e., the standard deviation of the pollution concentration in the vertical plane

h = effective stack height of source distribution, i.e., the average height of area source emissions in the k^{th} wind direction sector at radial distance ρ from the receptor

L = the afternoon mixing height

$T_{1/2}$ = assumed half life of pollutant, hours

The possibility of pollutant removal by physical or chemical processes is included in the program by the decay expression $\exp(-0.692\rho/U_{\ell}T_{1/2})$.

The total concentration for the averaging period is the sum of concentrations of the point and area sources for that averaging period.

2. METEOROLOGICAL PARAMETERS

2.1 Joint Frequency Function

It is necessary to have information on the joint frequency function $\phi(k,\ell,m)$ as input for the model. This function gives the joint frequency of occurrence of a wind direction sector k, a wind speed class ℓ, and a stability category index m. There are 576 entries in the table for the joint frequency function. This number of values results from the 16 different wind vectors, 6 wind speed classes, and 6 stability classes used in determining the frequency function.

Weather observations are taken hourly by meteorologists of the National Weather Service at airports serving major urban areas. In most circumstances, this weather data will be representative of the meteorological conditions of adjacent urban areas. This weather information for localities throughout the United States can be obtained from the National Climatic Center (NCC) located in Asheville, North Carolina. The revised version of the NCC program called STAR gives the proper form of the joint frequency function. The relation between the Pasquill-Gifford Stability classes and those used in the Climatological Dispersion Model are shown in Table C1.

Table C1

PASQUILL-GIFFORD AND CLIMATOLOGICAL DISPERSION MODEL STABILITY CLASSES

Pasquill-Gifford	P_m
1	1
2	2
3	3
4 daytime	4
4 nighttime	5
5 6	6

The wind speed U for the various weather bureau classes (Table C2) is taken as the central wind speed of the class. It should be noted that the central wind speed of the lowest wind speed class was arbitrarily taken as 1.5 meters per second. (1.30 m/sec when wind speeds are reported in miles/hour rather than in knots.) This means that light winds reported in the first wind speed class were rounded up to this value, since most operational wind instruments are designed for durability and also to windstand exposure to strong, gusty airflow. For these reasons, most wind sensors have a high starting speed, which can lead to the erroneous reporting of light winds as calms.

2.2 Wind Profile

To account for an increase of wind with height above a height of 10 meters (anemometer height) to the level of emission, a power law relation of the form

$$U(z) = U_{\ell} \, (z/z_0)^p \qquad \text{(C5)}$$

is used in the computational program. The exponent p depends on the stability class and is given in Table C3.

Table C2

CENTRAL WIND SPEEDS

Wind Speed Class	Standard Weather Bureau Class (knots)	Class Wind Speed (m/sec)	Standard Weather Bureau Class (mph)	Class Wind Speed (m/sec)
1	0-3	1.50	0-3	1.30
2	4-6	2.46	4-6	2.14
3	7-10	4.47	7-10	3.88
4	11-16	6.93	11-16	6.02
5	17-21	9.61	17-21	8.35
6	>21	12.52	>21	10.90

Table C3

EXPONENTS FOR WIND PROFILE

Stability class	Exponent P
1	0.1
2	0.15
3	0.20
4	0.25
5	0.25
6	0.30

2.3 Mixing Height

The magnitude of the mixing height undergoes considerable diurnal, seasonal, and annual variation. It is impractical to account for all such variations in detail. Nevertheless, some recognition is given to changes in the magnitude of the mixing height by assigning values to different stabilities according to Table C4. In Table C4, HT is the climatological mean value of the mixing height and HMIN is the nocturnal mixing height.

Table C4

MIXING HEIGHT

Stability class	Mixing height, meters
1	1.5 x HT
2	HT
3	HT
4 day	HT
night	(HT + HMIN)/2
5	HMIN
6	HMIN

2.4 Stability Classes

The lower layer of the urban atmosphere is generally more unstable than is the corresponding adjacent rural atmosphere. To account for this, modifications have been made to the stability class applied in the calculation of concentration from area sources. This modification consists of decreasing the stability class by one class with the exception of P_1 which is unaltered. This correction is not applied to point sources.

During the night, with a surface inversion condition and a rural class stability of P_5, the neutral stability class P_4 is assumed for both point and area sources. Otherwise, there is no modification of the stability classes applied to point source calculations.

2.5 Dispersion Functions

An analytical approximation to the curves of Pasquill and Gifford (these curves are reproduced by Turner[*]) for the vertical dispersion function $\sigma_z(\rho)$ is made by using an empirical power law in the form

$$\sigma_z(\rho) = a\rho^b \tag{C6}$$

The parameters a and b for various stabilities and ranges of distance ρ are given in Table C5.

An initial value of the dispersion function $\sigma_z(0)$ is used in the program to represent the vertical dispersion created by the roughness of urban topography (buildings). For area sources, it is possible to input a different value of initial σ_z for each stability class, that is six different values. Normally, the same value (30 meters) is used for all stability classes.

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[*] Workbook of Atmospheric Dispersion Estimates, HEW, 1970, Document No. PB 191482.

Table C5

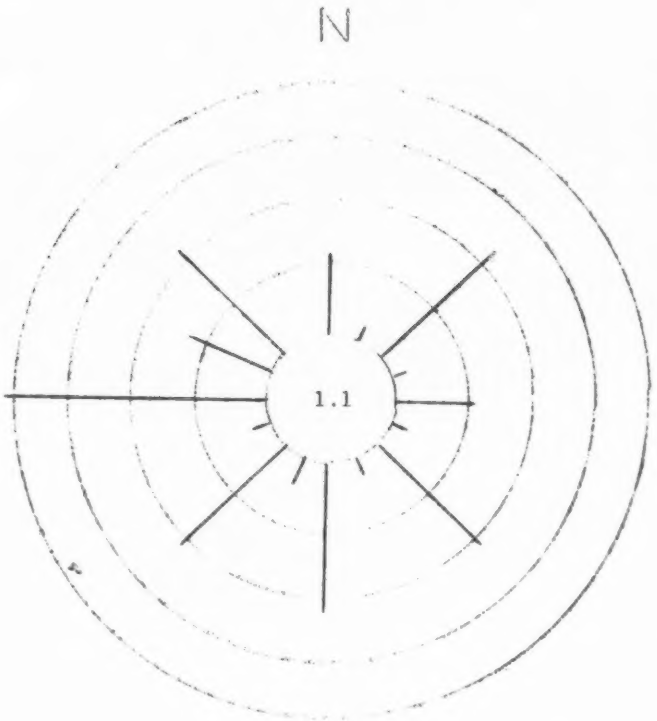
PARAMETRIC VALUES FOR $\sigma_z(\rho)$

Stability class	Distance, meters					
	100 to 500		500 to 5,000		5,000 to 50,000	
	a	b	a	b	a	b
1	0.0383	1.2812	0.2539×10^{-3}	2.0886	--	--
2	0.1393	0.9467	0.4936×10^{-1}	1.1137	--	--
3	1.0020	0.9100	0.1014	0.9260	0.1154	0.9109
4	0.0856	0.8650	0.2591	0.6869	0.7368	0.5642
5	0.0818	0.8155	0.2527	0.6341	1.2969	0.4421
6	0.0545	0.8124	0.2017	0.6020	1.5763	0.3606

Appendix D

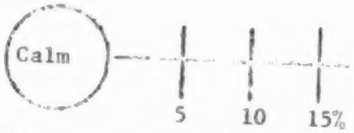
SURFACE WIND ROSES FOR WAUKEGAN, ILLINOIS; STOCKTON, CALIFORNIA; BURLINGTON, VERMONT; SHERMAN, TEXAS; PHOENIX, ARIZONA; AND PHILADELPHIA, PENNSYLVANIA

SURFACE WIND ROSE, JANUARY
WAUKEGAN, ILLINOIS



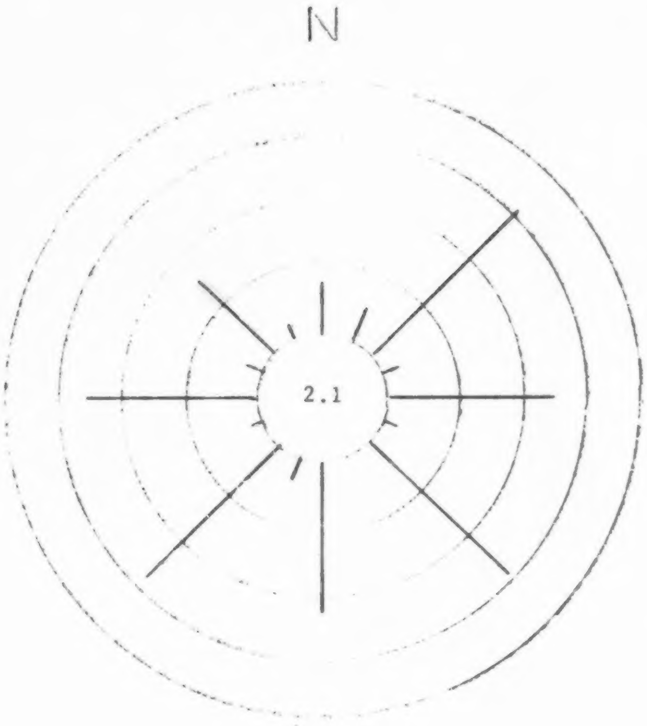
Based on four observations
per day for period
January 1938 - December 1939.

Legend

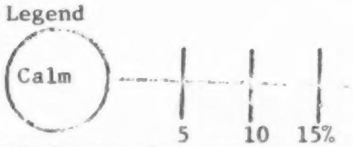


Windroses show percentage
of time wind blew from the
16 compass points or was
calm.

SURFACE WIND ROSE, JULY
WAUKEGAN, ILLINOIS

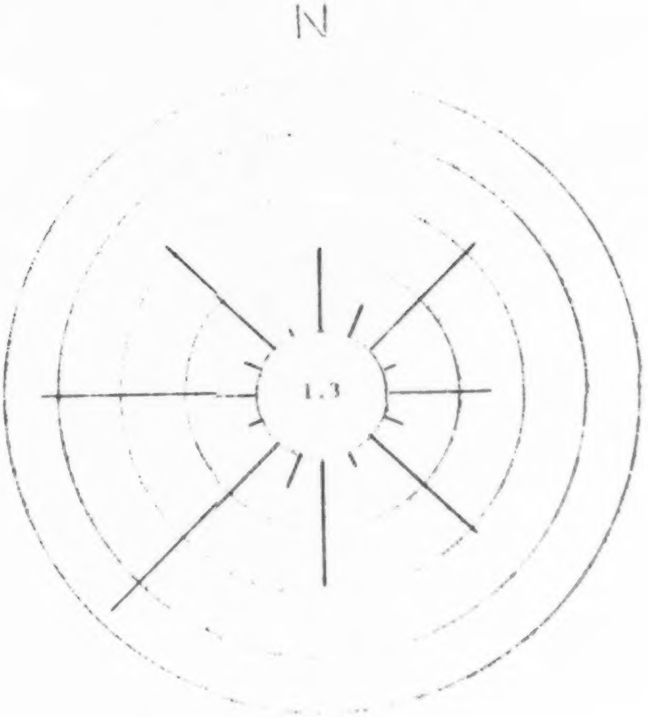


Based on four observations per day for period January 1938 - December 1939.



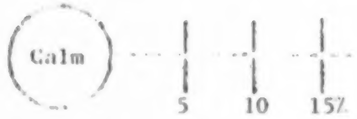
Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, ANNUAL
WAUKEGAN, ILLINOIS



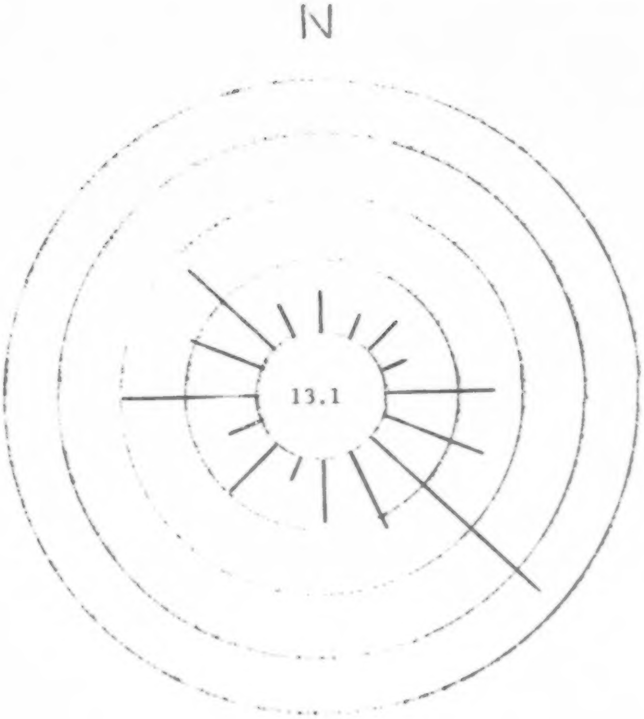
Based on four observations
per day for period
January 1938 - December 1939.

Legend

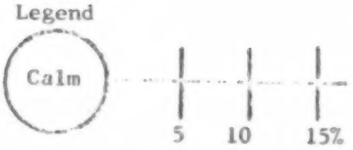


Windroses show percentage
of time wind blew from the
16 compass points or was
calm.

SURFACE WIND ROSE, JANUARY
STOCKTON, CALIFORNIA

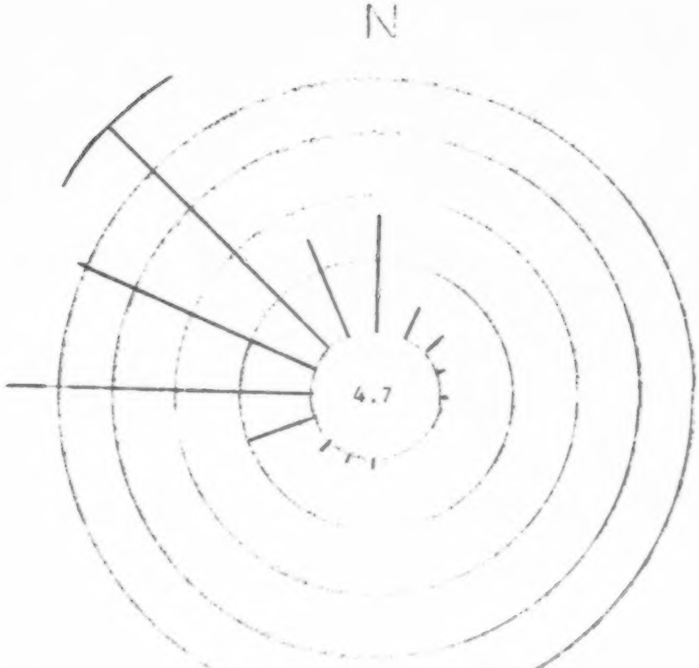


Based on hourly observations for period February 1941 - June 1946.



Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, JULY
STOCKTON, CALIFORNIA



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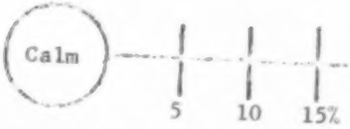
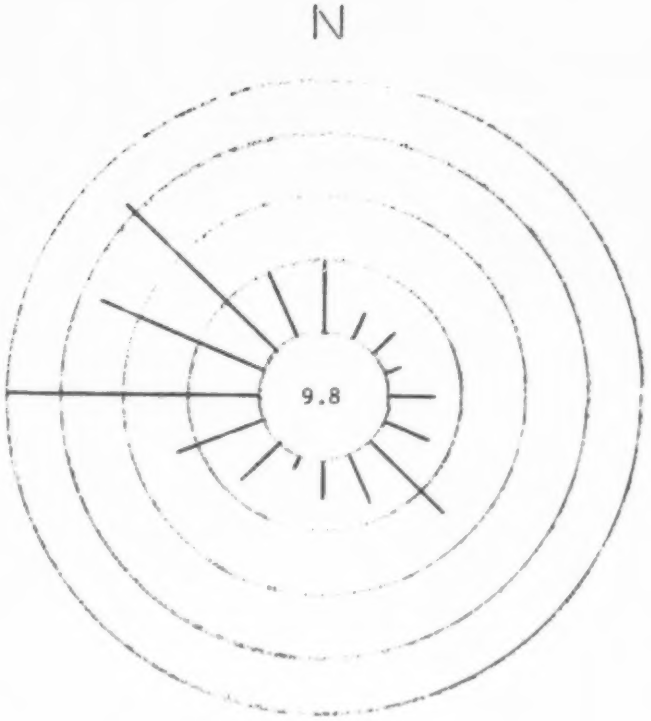


Based on hourly observations for period February 1941 - June 1946.

Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, ANNUAL
STOCKTON, CALIFORNIA



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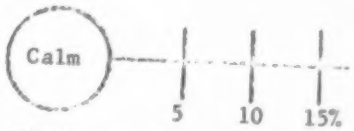
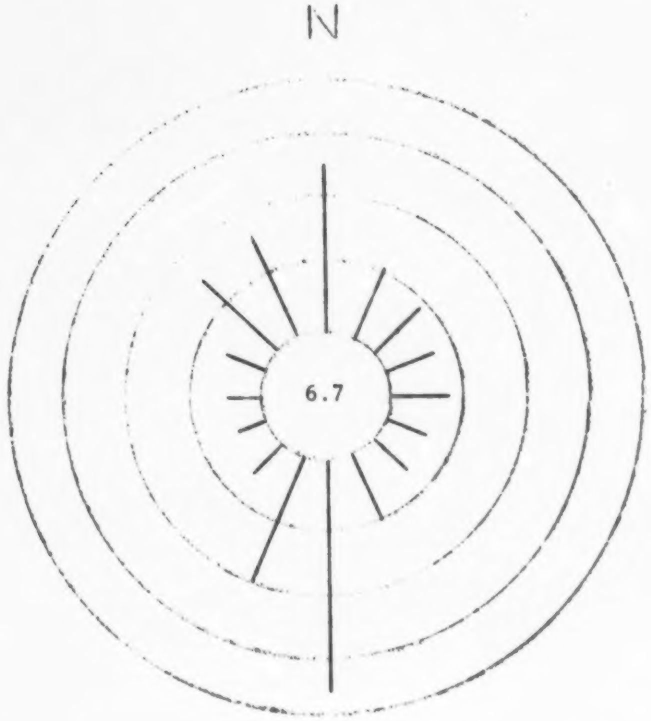


Based on hourly observations for period February 1941 - June 1946.

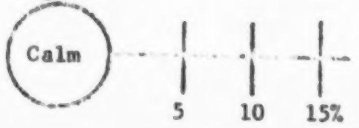
Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, JANUARY
BURLINGTON, VERMONT



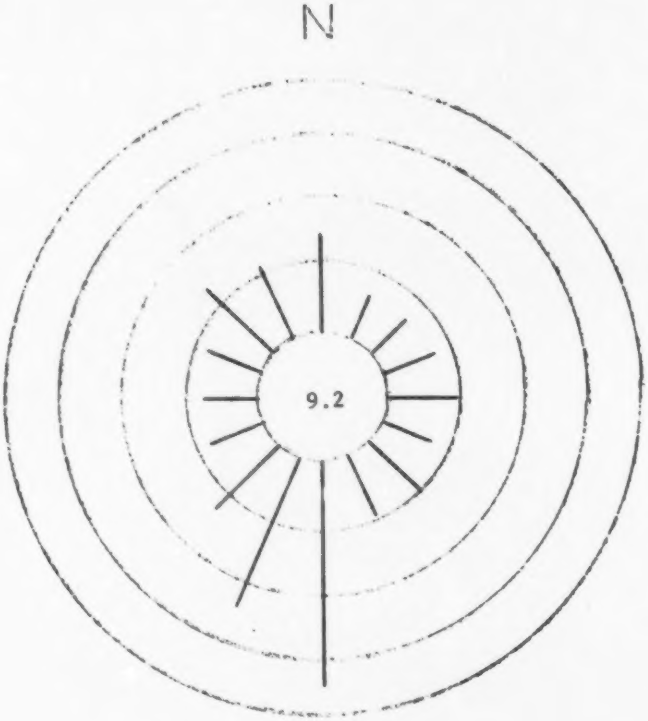
Based on hourly observations for period January 1948 - March 1968.

Legend



Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, JULY
BURLINGTON, VERMONT



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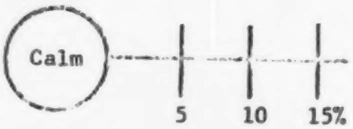
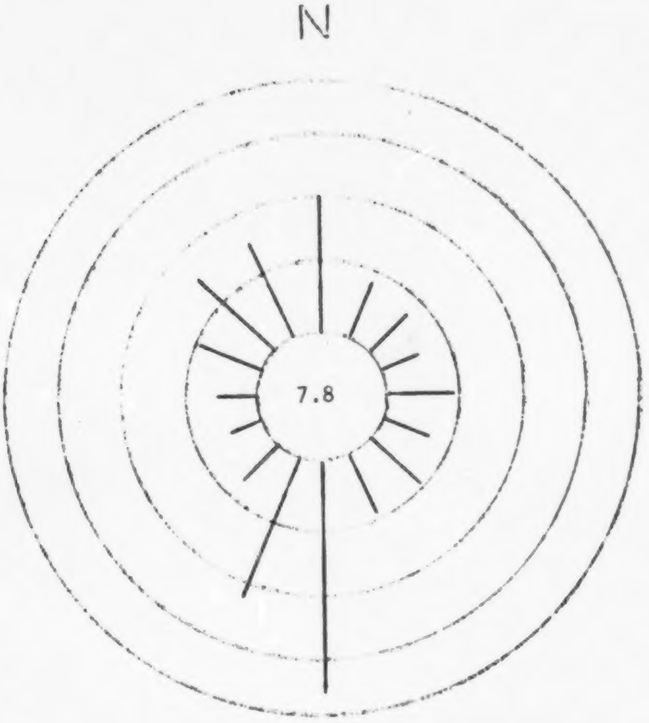
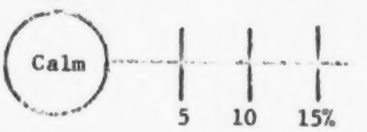


Based on hourly observations for period January 1948 - March 1968.

Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, ANNUAL
BURLINGTON, VERMONT

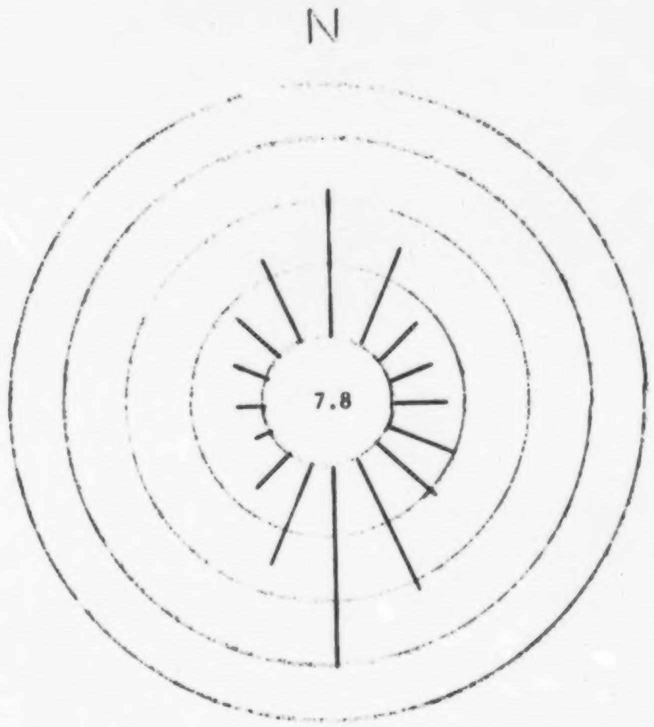




Based on hourly observations for period January 1948 - March 1968.

Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, JANUARY
SHERMAN, TEXAS



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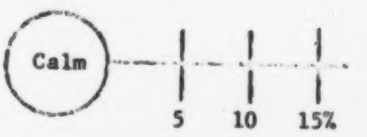
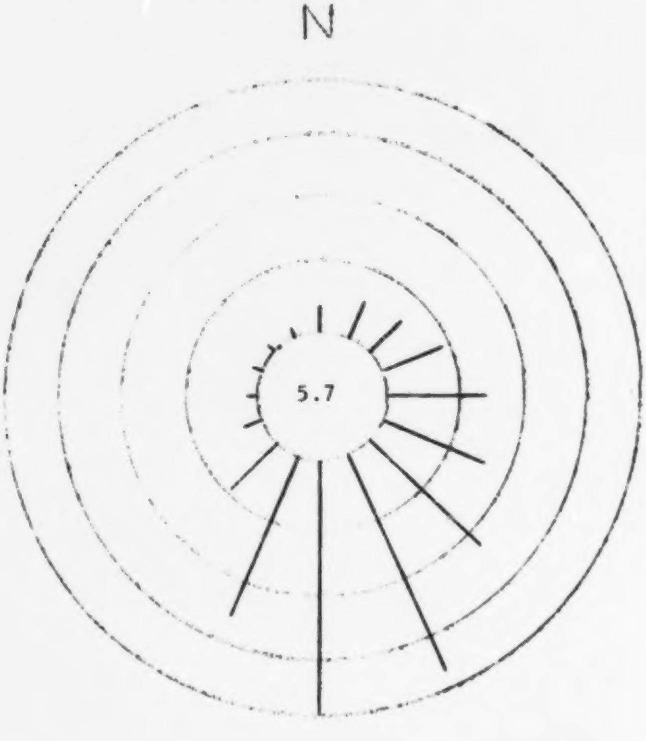


Based on hourly observations for periods January 1942 - January 1946, May 1946 - November 1946, and July 1948 - November 1968.

Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, JULY
SHERMAN, TEXAS



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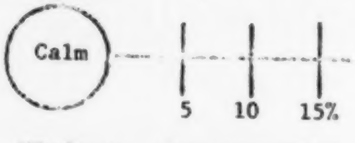
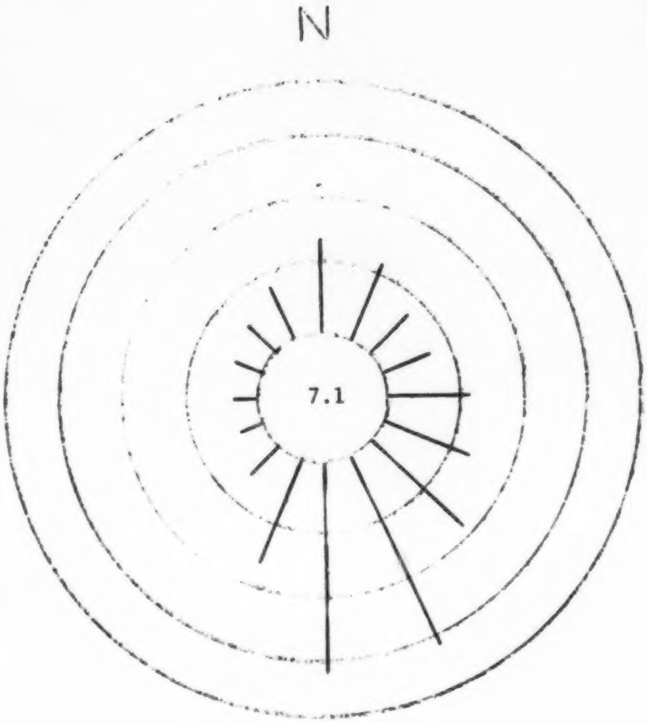


Based on hourly observations for periods January 1942 - January 1946, May 1946 - November 1946, and July 1948 - November 1968.

Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, ANNUAL
SHERMAN, TEXAS



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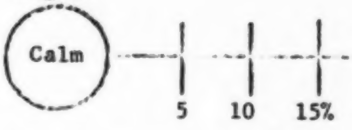
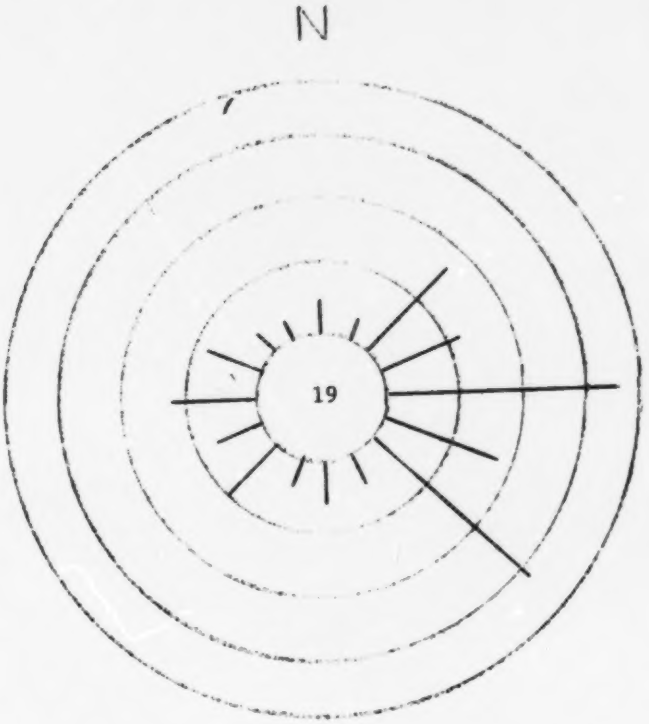


Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, JANUARY
PHEONIX, ARIZONA



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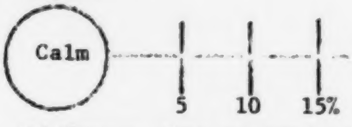
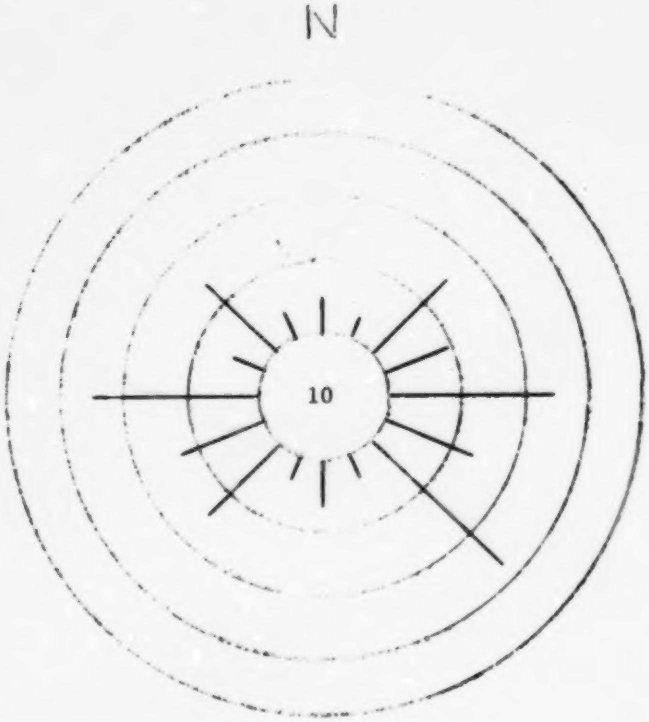


Based on hourly observations for period January 1951 - December 1960.

Windroses show percentage of time wind blew from the 16 compass points or was clam.

SURFACE WIND ROSE, JULY
PHEONIX, ARIZONA



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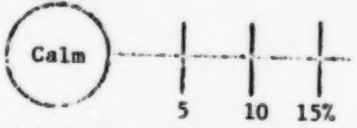
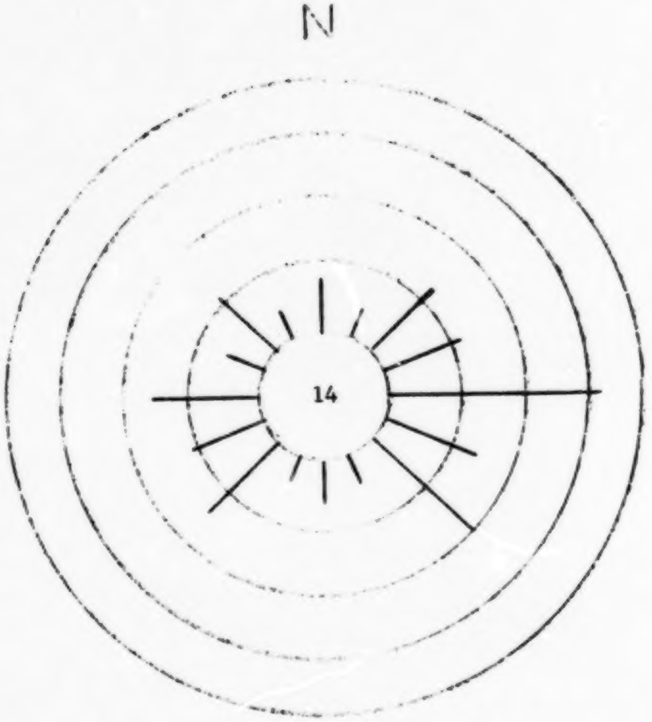


Based on hourly observations for period January 1951 - December 1960.

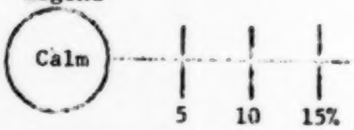
Windroses show percentage of time wind blew from the 16 compass points or was clam.

SURFACE WIND ROSE, ANNUAL
PHEONIX, ARIZONA



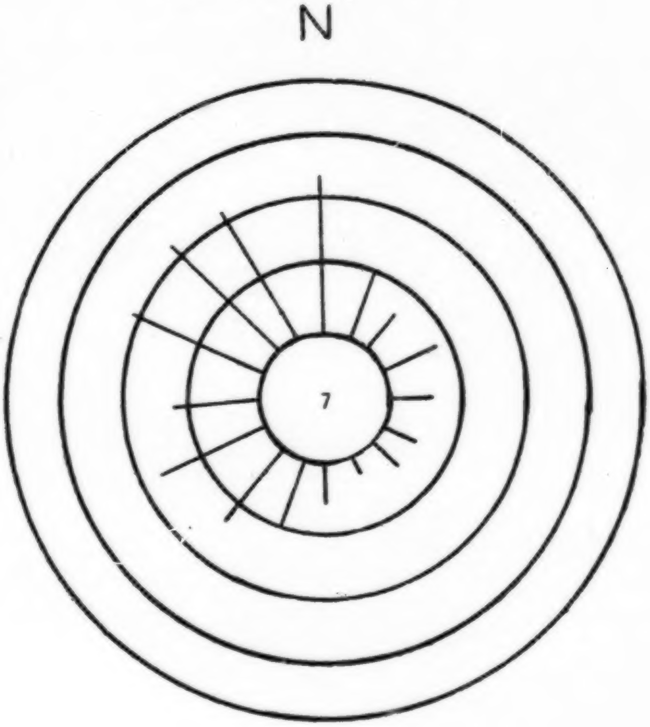
Based on hourly observations for period January 1951 - December 1960.

Legend



Windroses show percentage of time wind blew from the 16 compass points or was calm.

SURFACE WIND ROSE, JANUARY
PHILADELPHIA, PENNSYLVANIA



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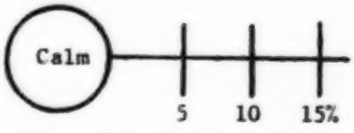
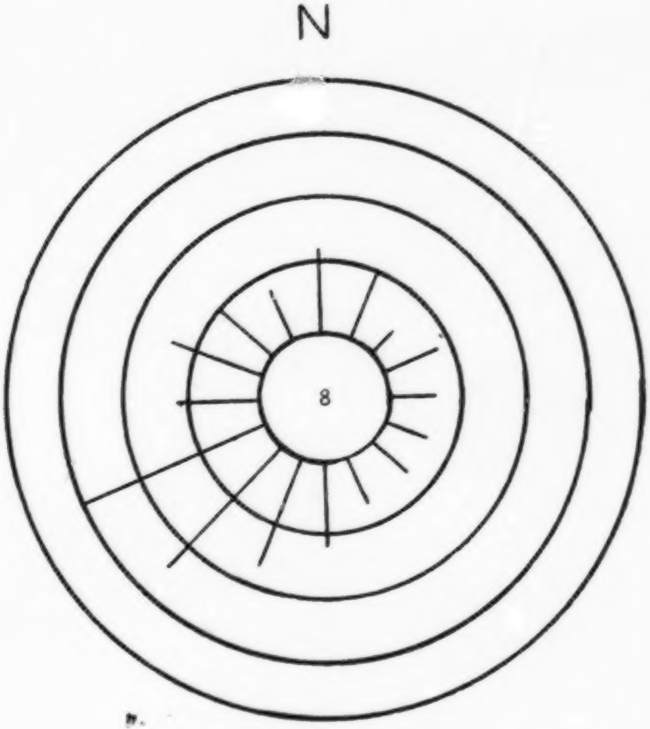


Based on hourly observations for period January 1951 - December 1960.

Windroses show percentage of time wind blow from the 16 compass points or was calm.

SURFACE WIND ROSE, JULY
PHILADELPHIA, PENNSYLVANIA



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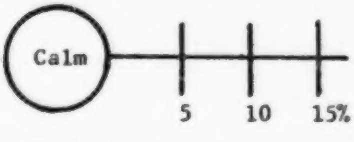

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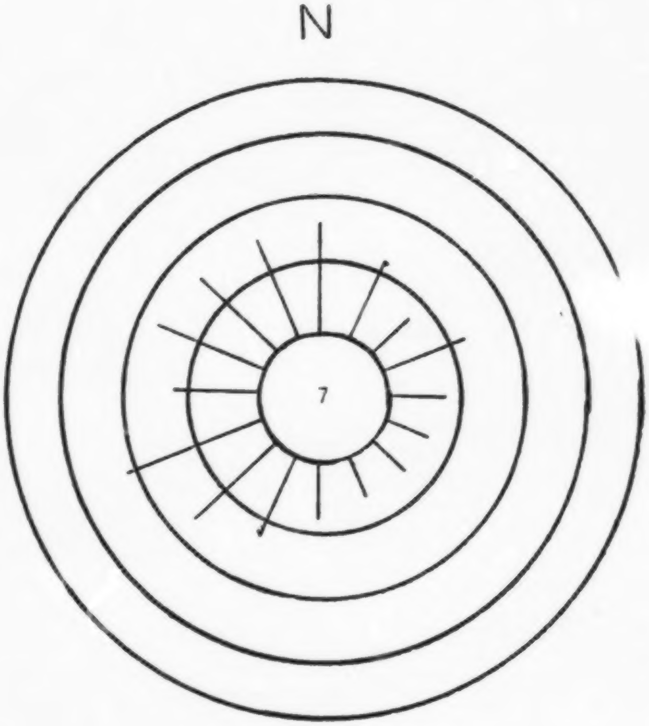
PHILADELPHIA, PENNSYLVANIA



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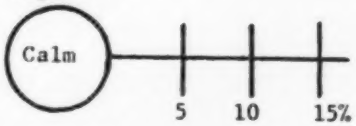
Legend



Windroses show percentage of time wind blew from the 16 compass points or was calm.